J. L. Robinson

AMERICAN PRACTICE OF SURGERY

A COMPLETE SYSTEM OF THE SCIENCE AND ART OF SURGERY, BY REPRESENTATIVE SURGEONS OF THE UNITED STATES AND CANADA

EDITORS:

JOSEPH D. BRYANT, M.D., LL.D.

ALBERT H. BUCK, M.D.

OF NEW YORK CITY

COMPLETE IN EIGHT VOLUMES

Profusely Illustrated

VOLUME FIVE

NEW YORK

WILLIAM WOOD AND COMPANY

MDCCCCVIII

CONTRIBUTORS TO VOLUME V.

EDWARD ARCHIBALD, M.D., C.M. (McGill), Montreal, Canada.

Lecturer in Clinical Surgery, McGill University; Attending Surgeon, Royal Victoria Hospital.

CHARLES H. FRAZIER, M.D., Philadelphia, Pa.

Professor of Clinical Surgery, University of Pennsylvania; Attending Surgeon, University, Episcopal, and Philadelphia Hospitals; Consulting Surgeon, Kensington Hospital for Women.

GEORGE C. HARLAN, M.D., Philadelphia, Pa.

Emeritus Professor of Diseases of the Eye, Philadelphia Polyclinic; Ophthalmologist, Pennsylvania Hospital; Consulting Surgeon, Wills' Eye Hospital.

FRANK HARTLEY, M.D., New York City.

Professor of Clinical Surgery, College of Physicians and Surgeons, Medical Department of Columbia University, New York; Attending Surgeon, New York Hospital; Consulting Surgeon, the General Memorial, the French, and the Nyack Hospitals.

CHARLES H. KNIGHT, M.D., New York City.

Professor of Laryngology, Cornell University Medical College; Attending Surgeon, Manhattan Eye, Ear and Throat Hospital, New York.

ROBERT LEWIS, Jr., M.D., New York City.

Professor of Clinical Otology, College of Physicians and Surgeons, Medical Department of Columbia University, New York; Attending Aural Surgeon, New York Eye and Ear Infirmary; Consulting Aurist, St. Francis and Flushing Hospitals, New York City.

CHARLES B. G. DE NANCRÈDE, M.D., Ann Arbor, Michigan.

Professor of Surgery, Medical Department, University of Michigan; Attending Surgeon, University of Michigan Hospital.

JAMES E. NEWCOMB, M.D., New York City.

Instructor in Laryngology, Cornell University Medical College; Laryngologist to the Roosevelt Hospital, New York.

HENRY O. REIK, M.D., Baltimore, Maryland.

Associate in Opththalmology and Otology, Johns Hopkins University; Attending Surgeon, Baltimore Eye, Ear, and Throat Hospital.

JOHN D. RICHARDS, M.D., New York City.

Aural Surgeon, St. Mark's Hospital, New York City.

JAMES S. STONE, M.D., Boston, Mass.

Surgeon, House of the Good Samaritan; Assistant Surgeon, Infants' Hospital; Junior Assistant Surgeon, Children's Hospital, Boston.

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SURGICAL AFFECTIONS AND WOUNDS OF THE HEAD.

By EDWARD ARCHIBALD, M.D., Montreal, Canada.

In spite of the fact that wounds of the head frequently involve not alone the scalp, but also the skull and the brain coincidently, it is necessary, for text-book exigencies, to discuss in separate sections the injuries and diseases of these various parts. Therefore, in the following pages we shall follow the ordinary rule and describe successively injuries and diseases, first of the cranial soft parts, then of the cranium, and finally of its contents, the meninges and the brain.

I. THE CRANIAL SOFT PARTS.

Anatomical Peculiarities.—The scalp presents many anatomical peculiarities with a marked surgical bearing. It is composed of three chief layers of tissue: the skin, the fronto-occipital muscle with its aponeurosis, the galea, and finally the periosteum or pericranium. These three are bound together by two layers of areolar tissue. That which binds the skin to the occipito-frontalis muscle and the galea is in the main dense and firm; only over the forehead, lower temporal and lower occipital regions does one find the skin loose and movable upon the underlying parts. On the other hand, the areolar tissue between periosteum and galea is loose-meshed to such a degree that the scalp as a whole is freely movable upon the underlying bone.

The blood supply to the scalp is especially good, though the skin is relatively better furnished than are the deeper parts; the arteries supplying it take a horizontal course under the surface in such fashion that, when there occurs a flap wound of the scalp, the main artery supplying that region is contained in the flap and is not torn across. Where the flap contains the deeper parts, including the galea and the areolar tissue lying underneath it, these are in much greater danger of necrosis than is the skin. Still, the occurrence of necrosis of the scalp from circulatory failure is a rare event. I well remember the remark of a surgeon who, when asked why, in throwing down a flap in the operation for cerebral abscess, he made it with the base upward, thus cutting off the temporal blood supply, replied that he hardly knew how one could cut the scalp in such a way as to abolish the circulation.

The periosteum receives part of its blood supply through emissary vessels from inside the cranium and from the diploë; and it is the rupture of these that is the cause of the more extensive hæmatomata which lie under the pericranium.

Of the lymphatics, those of the frontal region drain into the submaxillary nodes; those at the side of the forehead and those of the temporal region into the parotid; those situated behind the ear into the mastoid; and those of the occipital region into the occipital nodes.

Incised, Punctured, and Contused Wounds.—It is hardly necessary to state that the nature of the wounds thus caused depends upon the character of the instrument and the direction of the blow, whether slanting or perpendicular.

Incised wounds may be either linear or in the shape of a flap; and on account both of the skull's convexity and of the fact that the blow is frequently slanting, the latter variety is quite frequent. Those which involve merely the skin gape very little on account of the close connection between the skin and the occipito-frontalis aponeurosis. But when the latter structure is cut through as well, especially if the cut be transverse to its fibres, the edges of the wound immediately separate more or less widely. The course of these wounds under treatment is nearly always favorable because of the excellent circulatory conditions present; and probably this fact is largely responsible also for the comparative rarity of infection. In their tendency to quick healing they resemble wounds of the face. The success of the oculist in operating upon the very vascular tissue of the eyelids, in spite of a somewhat inevitable lack of thorough asepsis, is well known; and I imagine that a similar degree of vascularity is responsible for the smooth healing of scalp wounds. Not only so, but the approximation of the edges of scalp wounds is very perfect. The result is that clean-cut wounds of the scalp heal with an extraordinary absence of disturbance from infection or other cause of delayed union.

Punctured wounds usually penetrate as far as the bone. The point of the instrument may here pursue its course in a slanting direction and perforate the scalp at a distance. One must always be more suspicious of these than of other varieties simply because the depths of the wound are not displayed, and we are unable to say whether more serious lesions, such as perforation of the cranium, are present or not, in the absence of distinct cerebral symptoms. Yet when they are caused by a clean instrument their course is also favorable and very rarely gives rise to anxiety.

Contused Wounds.—The impact of a blunt instrument may or may not cause an open wound of the scalp. If the skin remain intact, hæmatoma is very likely to form. If the blow was vertical, the hæmatoma is likely to remain localized to the area struck, and to be situated externally to the galea. If, on the other hand, the blow was slanting, the resulting pull upon the skin and the galea, taken as a whole, usually tears the vessels in the subaponeurotic areolar tissue, and the subsequent hæmatoma is situated more often under the aponeurosis. Here the effusion of blood may be very large; and, the areolar tissue being loose-meshed, the blood may spread easily over a great extent of the convexity of the skull. However large it may be, there is very apt to form at its edge a ring of indurated tissue representing the natural inflammatory response, while the centre of the hæmatoma remains soft. Here we must repeat the classical warning against mistaking this condition for depressed fracture, though the differential diagnosis is really not often difficult. In the case of hæmatoma the indurated edge, upon palpation, is found to rise above the level of the surrounding bone; and if one press firmly enough one can readily indent it. On the other hand, it must not be forgotten that a depressed fracture often lies hidden under a hæmatoma.

The effusion of blood may be situated under the periosteum alone. Such a condition I have never seen, save in infants; and it is generally recognized that it hardly ever occurs in adults. This fact von Bergmann explains upon the ground of the greater vascularity of the pericranium in infants, in whom growth of the bone and periosteum is very rapid. I imagine, however, that in addition to this factor we must recognize the influence of the greater laxity of the infant's scalp upon the cranium, a condition which makes easier the sliding of the soft parts upon the bone. This, again, is certainly the chief mechanical cause of hemorrhage under the pericranium. These subperiosteal hæmatomata present the same characters of indurated edge and soft centre as do the subaponeurotic ones, yet differ from them in being confined to the area of one bone, usually the parietal, because of the firm attachment of the periosteum along the suture lines.

If the impact of a blunt object go beyond mere bruising and inflict a wound, this latter will be found most frequently, as one would expect, to be irregular and jagged in its outline, with bruised edges; or, if the blow were slanting, it will very probably assume the shape of a flap, the object of violence taking a hold of the scalp at its point of impact and then tearing a portion of the scalp loose in the direction of the force. In such a case the flap is found to be bruised, while its sides are linear and clean-cut, although upon close examination minutely irregular. This is a very striking fact, that a blunt object may cause a linear wound with edges apparently as clean cut as any made by a sharp instrument. The explanation must really lie in the bursting or tearing principle, though exactly how the scalp is burst is a little difficult to understand. Once a slight tear is made, any pull, as from a tangential blow, will naturally tear the scalp extensively. The greater the violence of the blow and the smaller its area of impact, the less likely are we to get bruising and the more likely to get apparently clean-cut linear wounds. The application to forensic medicine is evident. In these flap wounds it is usually the skin and galea that are torn, the pericranium remaining intact. Nevertheless, if the wound be large, the pericranium too is very apt to be peeled off irregularly in spots.

Perhaps the worst tears of the scalp are those seen in the explosive wounds of the skull characteristic of the action of the modern small-calibre bullet at very close range. Of this, more later on.

TREATMENT.—The treatment of scalp wounds gives, upon the whole, very gratifying results, and the reason of this has been already indicated. Nevertheless, treatment must be careful and thorough in order to obtain these results. Everything depends upon the proper cleansing of the wound. In all cases it is necessary to shave the surrounding scalp for a variable distance, and to scrub the neighborhood thoroughly with soap and water, placing gauze or cotton pledgets in the wound to prevent as much as possible the washings running into it. Lately I have used with success the benzene-iodine method of Heusner, which is intended as a substitute for soap and water. The formula is as follows:

Benzene........................	750 parts.
Liquid paraffin..................	250 parts.
Iodine	1 part.

This solution, by virtue of the benzene contained in it, cleanses the skin thoroughly of all fatty matter, and does so more quickly and perhaps more effectually than soap and water. The skin is well scrubbed with gauze sponges soaked in the preparation, and the benzene is then removed with alcohol. This, I think, is sufficient cleansing. If the wound has been inflicted by a clean, sharp instrument, there should be no hesitation in sewing it up completely.

In the case of punctured wounds treatment will vary according to the aseptic or septic condition of the instrument used. Here general surgical principles hold, as in other parts of the body. The skin immediately closes over a puncture, and thus more or less normal conditions of mutual tension are restored. Now Friedrich has shown that when the subcutaneous tissues retain their normal condition of mutual tension, infection deposited in them is very apt to progress, whereas, in wounds in which there is no tension, that is, which are laid open, the same infection is overcome. It follows that in punctured wounds any infection carried in by a pointed instrument takes with it so much the more danger; therefore, where there is reasonable ground for belief that the instrument carried in infection, it will be better to lay open the whole punctured tract and cleanse it. If this tract can be excised, as ought to be usually the case, one may safely suture the wound completely; otherwise it would be best to leave it at least partly open with adequate drainage. These remarks apply with added force when there is reasonable suspicion that dirt containing the tetanus bacilli has been carried in by the instrument. In such cases, besides freely opening and sterilizing the wound, antitetanic serum should be given prophylactically, and repeated once in the course of a week or ten days.

In the case of contused wounds one should remember, first of all, that even very large flaps will frequently reunite if restored to their proper continuity. As to the evidence of contusion of the edges, it would be a mistake to determine early that their vitality was destroyed, and to remove primarily any material amount of tissue. Very often the excellent circulation in the scalp is sufficient to rescue tissue which is apparently hopelessly bruised. Therefore, where there is no gross infection, the flap should be sutured in position, loosely, so as to avoid all tension, and one should wait to see what nature will accomplish. If, however, the wound is soiled with particles of earth, coal, or other foreign agents, it is absolutely necessary to devote a great deal of time and pains to the removal of all these foreign particles; and this is certainly best accomplished by clean cutting with a sharp scalpel. If, as is frequently the case, the dirt is ground into the subaponeurotic areolar tissue for some distance underneath the flap, it would be better to cut out this fibrous tissue completely with scissors. With such a careful and painstaking operation I have secured primary union throughout and a perfect scar in such a cosmetically important region as the forehead, and in spite of extensive soiling of a wound.

In the process of cleansing and trimming these contused wounds of the scalp, it is of more importance to be sure of the vitality of the galea and subaponeurotic tissue than of the skin. Certainly the blood supply to the former is much the poorer, and its liability to sloughing and infection much the greater. It has been indicated how infection is to be avoided. Sloughing also may be avoided in many cases, if the portions of hopelessly bruised tissue be cut away until fresh oozing of blood occurs. Under such circumstances the wound may be sutured completely and healing by first intention obtained. But if one is in doubt as to the vitality of this deep tissue, or as to the complete removal of possible sources of infection, it will be better to use drains freely, preferably the cigarette drain.

Scalping.—Another extremely severe injury, seen nowadays only in civil life, is that of avulsion or scalping. Almost invariably the victims are young women, employées in a factory, whose long hair is caught by a revolving belt. The tear frequently is from before backward, and the line of separation runs across the forehead above either ear, and back toward the middle line in the neck region, the two sides running to a point. After proper cleansing, if the scalp still hangs by a pedicle, it should be loosely replaced on the cranium; a fair portion of it may reunite. Otherwise Thiersch's skin-grafting should be done early. Mellish records a case of complete loss of the whole scalp together with the skin of the neck as low down as the fifth cervical spine, which he caused to heal within two months by the employment of Thiersch grafts.* The wound should be treated in other respects on general principles. The prognosis is not very dark. Of seventeen cases reported by Gerok, only three were fatal.† The total number of recorded cases is 40. (Miyata.‡)

* Mellish: Annals of Surgery, 1904, vol. xl., p. 644.

† Gerok: Bruns Beiträge, 1892, Bd. ix., p. 329.

‡ E. Enz: Correspondenzblatt f. Schweizer Aerzte, 1905, xxxv., p. 701.—Lotheissen: "Ueber Scalpirung und ihre plastische Behandlung." Wien. med. Woch., 1906, No. 37.—Miyata: "Beiträge zum Capitel der totalen Scalpirung." Arch. f. klin. Chir., Bd. 85, 1908, p. 963.

Complications.—*Mild infection* in scalp wounds is not of great moment when confined to the skin, save where erysipelas develops. On account of the dense, close-meshed subcutaneous tissue the tendency is toward the formation of a localized abscess of small size, as in the tissue of the palmar fascia. Infection under the galea, however, is of considerable moment, both because of its liberty of spread in the loose subaponeurotic tissue and of its quite direct vascular connection through emissary veins with the meninges and brain. A subaponeurotic phlegmon may extend over the whole vault; there is nothing to stop it. If the periosteum were not originally stripped up by the trauma, the infection may destroy it, lay bare the cranium, induce a superficial or even deep necrosing osteitis, inflame the dura by direct extension through the bone, form in the communicating veins thrombi which may spread into the main sinuses, and ultimately cause fatal meningitis or even cerebral abscess. Such a march of events I find in the records of the Royal Victoria Hospital. The ounce of prevention is worth in these cases the full value given it by the proverb; and the important points in prevention are early and thorough disinfection of the wound, not alone by antiseptic irrigations, but by actual cutting away of tissue which is likely to contain the elements of infection; and secondly, where necessary, by the free use of drains

Wounds that come under observation when infection is already marked are to be treated, like any other cellulitis, by free incisions and drainage. Whether one shall use in preference small incisions and artificial hyperæmia (Klapp's cups or Bier's rubber bandage) must still remain a matter of individual judgment. Certainly those unfamiliar with the method cannot afford to gain their first experience of it on this part of the body (see Keppler, *Münch. med. Woch.*, 1905, Nos. 45–47). The use of caustic antiseptics, such as pure carbolic acid, is, in my opinion, never justifiable, save possibly in pure tuberculous infections. When swabbed over infected surfaces they destroy the superficial tissue and leave the bacteria that are always present in the deeper layers a freer field and lessened resistance; such, at least, is my experience.

Wounds of the Head at or before Birth.—That the head of the fœtus in utero may be the subject of trauma seems to be an established fact, although of the few cases reported as such the majority have been proved to be due to injury during labor. Injury before birth is probably caused by the propulsion of the head against the promontory of the sacrum through such accidents as a fall or a kick. Children have been born with clear evidences of a healed wound of the scalp.

The injuries evident upon the head after birth are for the most part due to pressure of the maternal parts, in particular the promontory, or to the use of forceps, or to other manipulations of the accoucheur. Pathologically these injuries may consist in abrasions of the skin, œdema, and serous or bloody effusions under the skin. A description of these may well be left to text-books on obstetrics and pediatrics; yet one of these conditions, that of hæmatoma of the scalp in infants, deserves perhaps some consideration, inasmuch as it may become the object of surgical intervention. This can hardly ever become necessary with the other lesions mentioned.

Effusion of blood in the soft coverings may take place into the subcutaneous tissue, or into the loose areolar tissue underneath the occipito-frontalis muscle, or still deeper under the periosteum itself. A hæmatoma occurring in this last situation has been given the special name of cephalhæmatoma. As to the first it may be said that subcutaneous hæmatomata of varying size are of very frequent occurrence, but of slight practical importance. In a series of 74 post-mortems on infants dying in the Montreal Maternity Hospital, the reports of which I was kindly allowed to analyze by the pathologist, Dr. McCrae, I found such subcutaneous hemorrhage in over 40. Such hemorrhages are the natural result of the traumatism to which the head is subjected during labor. Effusions situated underneath the galea are comparatively rare. Those under the periosteum have been estimated at 1 in every 200 to 300 cases. In the series above mentioned I found it in 2 cases; while in another series of 201 post-mortems upon foundlings I found it in five instances. When subcutaneous the ecchymosis is rarely of any great extent; being due to superficial trauma, it soon disappears like any other bruise. When the blood is situated underneath the galea, but outside the periosteum, it may in some cases extend over a large area, the areolar tissue in this situation being loose-meshed and giving but little resistance to the spread of the blood; and besides, unlike the conditions existing in the pericranium, close attachment at the suture lines does not occur here.

Cephalhæmatoma.—When situated under the periosteum the hæmatoma is usually confined to the area of one bone. It is a little difficult to explain the mechanism of an injury which produces an effusion of blood underneath the periosteum. According to Fritsch it is due to the pull exercised on the scalp by the firm ring of maternal tissues at the moment when the cranium of the child retreats upon the cessation of a labor pain. This would apparently have the effect of sliding the pericranium forcibly over the bone with the result of tearing the venous radicles which pass between them. I am unaware that this explanation is more than theory. On the other hand, in certain cases, the effusion can be definitely traced to a fracture or depression of the bone, and I have come across such an instance in one of the foundling post-mortems above referred to.

In cephalhæmatomata the blood seems to escape gradually rather than rapidly. From being a very small collection on the first day, it may become, during the next two or three days, quite large, and it is probable that this is due to the increased blood pressure consequent upon the child's crying. While the œdematous effusion called the caput succedaneum is observed immediately upon birth, a cephalhæmatoma, for the above-mentioned reason, is frequently seen only on the second or third day, having only then attained dimensions of clinical significance.

These effusions show, pathologically, an interesting picture from two points of view. In the first place, from the fact that they are situated under the periosteum, which they lift away from the bone, their periphery will naturally become indurated, not only from the infiltration of the soft parts, but also, in the course of time, from the gradual new formation of bone proceeding from the still-functioning periosteum. This bony growth goes on chiefly at the periphery, but may also occur over the convexity of the hæmatoma, in which situation, however, it is usually no more than fragmentary. The simulation of a depressed fracture is evident. On the other hand, if the blood be not quickly absorbed, as is not infrequently the case, it seems to exercise to some extent an osteoclastic effect on the bone upon which it rests; so that in post-mortem reports one frequently finds mention of an erosion of the cranial bone involved; indeed, upon rare occasions the bone has been found entirely perforated. Part of this effect is probably due to the lifting of the pericranium from the bone. In the post-mortems on infants already referred to I found both these points regularly recorded.

The second point concerns the absorption of the effused blood. This is usually complete within from a few days to a fortnight; yet not infrequently, for some reason or other, one finds it persisting for weeks or even months as a sort of blood cyst, usually mixed to a certain extent with serous fluid. In one case, coming to autopsy at the age of eleven months and twenty-one days, there were evident the remains of an old hæmatoma undergoing absorption; in another case, forty-six days old, there was still present a tumor of clotted blood measuring 4 cm. in diameter and 2 cm. in depth. Termin, whose article upon the subject is classical, found that the reabsorption of blood occupies on an average from one to two months.

Symptoms.—A cephalhæmatoma appears over one or other parietal bone upon the second or third day after birth, forming a roundish, yet flattened, tumor, evidently deeply situated, which, if large enough, may give a sense of fluctuation. Frequently its shape resembles that of a large watch-glass. Its increase in size is usually slow and is completed within two or three days.

Diagnosis.—Its differentiation from caput succedaneum has been already referred to. From a meningocele or encephalocele it may practically always be distinguished by its difference in situation, the one being with great regularity in the middle line, and the other over the parietal region. A cephalhæmatoma is tenser than either of these and is not influenced by intracranial changes.

Treatment.—No treatment is usually necessary; the effused blood is spontaneously absorbed. Where, however, after the lapse of ten or fourteen days, there are no evidences that absorption is taking place, it will be advisable to aspirate the fluid blood because of the danger of its osteoclastic effect upon the underlying bone. If, because of clotting, aspiration be unsuccessful, it will be advisable to incise the swelling and turn out the coagula.

Tumors of the Cranial Soft Parts.—I. NON-NEOPLASTIC SWELLINGS.—*a. Air Collections in the Scalp.*—It is evident, from anatomical reasons, that air is found under the scalp only as the result of some fortuitous communication with the air-containing spaces of the skull, in particular the frontal and mastoid sinuses. The most frequent causes of such a communication are, as one would expect, trauma and infection. These collections of air in the scalp are found in two forms: as the ordinary diffuse subcutaneous emphysema, and as a localized collection under the pericranium, for which the name of pneumatocele of the cranium was first proposed by Chavance and Wassy.

Emphysema of the scalp is practically found to be the result of a fracture which has broken into a frontal or mastoid sinus; as a matter of fact, much more frequently the former than the latter, which, indeed, is very rare. Its extent is usually confined to the head and face, and its origin, frontal or mastoid, is easily determined by the history of injury, and the manner of spread. The latter is best seen under forced expiration, which always increases the extent of the emphysema. Very rarely it may spread to the trunk and arms. Treatment is usually quite unnecessary, as the air is absorbed within a very few days.

Pneumatocele of the cranium is a more interesting condition. McArthur * has lately reported a case, and at the same time reviewed the literature up to date. Here the air is collected between the pericranium and the bone, and forms a definite tumor the limits of which are more or less fixed by the attachments of the periosteum to suture lines. Its situation, naturally, is either the frontal or the occipital, especially the lateral, or masto-occipital, region. The condition is rare. von Bergmann, in 1900, refers to 27 recorded cases, and McArthur, in 1905, to 33. Of these, 23 were occipital and 10 frontal.

As to etiology, it is admitted that trauma and the caries of infection play the chief parts; in McArthur's cases these causes were each responsible for 10. In the 13 others, apparently of spontaneous occurrence, operation failed to discover the track of communication, and the matter remained uncertain. In explanation it has been suggested that the communication with the respective sinuses must be congenital or must exist alongside of vascular channels; and, indeed, Flesch has shown that in old people the bony canals of vessels may enlarge by a process of bone reabsorption.

The symptoms follow rationally upon the cause, the anatomical situation, and the gaseous nature of the tumor. First of all, as the air sinuses do not form before the tenth year, a pneumatocele cannot occur before this age. When it is present, one is able in some instances to cause its partial or complete disappearance by steady pressure; contrariwise, it will grow larger upon forced expira-

* McArthur: Jour. American Medical Association, May 6th, 1905.

tion. Its circumscribed situation under the pericranium gives it a semiglobular outline, and to palpation an even elastic resistance. Moreover, if the tumor is present for any length of time, the periosteum, just as with blood collections, forms a rampart of new bone round the circumference of the tumor, the firm, indurated edge notoriously simulating the border of a depressed fracture. Upon percussion one finds naturally a tympanitic note. Subjective symptoms are occasionally present, particularly a sound as of rushing air or water in the ear if the tumor be occipital, in the nose and throat if it be frontal. In extent the swelling may not exceed that of a cherry; or again, though indeed rarely, it may lift the periosteum from the sutures and reach from eyebrow to occiput.

The differential diagnosis is not difficult. Among the signs which contribute most to the making of a diagnosis, the tympanitic percussion note is undoubtedly the most valuable. From meningocele it differs in its lack of pulsation, and also in situation. The latter is usually found in the middle line, while pneumatocele occurs on the lateral aspect of the cranium. It may also be confounded with a cold abscess; yet the latter is rarely for long subperiosteal, and will therefore lack the peripheral ridge of new bone characteristic of the gaseous tumor; moreover, it will give a flat percussion note.

Treatment.—Not much is to be hoped for except from an operation. Aspiration followed by compression has succeeded in very few of the cases. Still, the harmlessness and ease of the procedure justify a preliminary trial of it. This failing, one should incise; if the communication be found and be very small, mere packing with gauze will probably suffice to obliterate it by upgrowth of granulation tissue. Kramer,* however, after two failures, was obliged to cover it with a Koenig-Mueller osteoplastic flap, which succeeded. Frequently the communication cannot be discovered, and one must content one's self with packing the wound.

b. Pericranial Sinus (*Sinus Pericranii*).—In 1850 Stromeyer† described for the first time the occurrence of a blood cyst between the pericranium and the bone. Later observations have shown that the lesion is nearly always traumatic in origin, is situated in the middle line over the forehead or the vertex, and contains circulating blood which communicates usually with the longitudinal sinus by a large emissary vein. To the condition Stromeyer gave the name of pericranial sinus. It does not occur frequently. In 1886 Lannelongue was able to collect no more than seven cases, and Littauer in 1904 reported the tenth case.‡ Its size is never greater than that of a walnut; and, on palpation, it is elastic and clearly a cyst. By pressure it may be made slowly to disappear, whereupon it is sometimes possible to feel the edges of the bony defect, or a ring of bony overgrowth at the periphery of the collection. Communicating as it does with

* Kramer: "Zur Lehre von der Pneumatocele Cranii." Centralblatt für Chir., 1896, p. 497.
† Stromeyer. Deutsche Klinik, 1850. ‡ Littauer: Berl. klin. Woch., 1904, May 30th.

the intracranial sinuses, any condition which increases intracranial pressure will naturally induce a rise of tension in the sinus pericranii as well as in the cerebral veins. Thus it will be found to become tense when the head is put low, as in bending. The treatment of the condition hitherto has been usually confined to continued compression. Franke* operated successfully on his patient in two stages, first opening the cyst and tamponing firmly, and later closing the osteal defect with filigree wire. Harvey Cushing† has seen two cases develop in connection with cerebral tumor, due doubtless to the intracranial venous stagnation associated therewith. In these, the sinus disappeared after a decompressive operation had been done.

c. *Sebaceous Cysts; Wens.*—The scalp is a favorite ground for the development of sebaceous cysts. Etiologically they are pure retention cysts of the hair follicles or sebaceous glands; and therefore a region of the skin which is especially rich in these, and which besides is exceptionally thick, would naturally be more disposed to the development of such retentions. Anything that closes the duct of a sebaceous gland is in this sense a factor in causation. Probably chronic irritation, such as the rubbing of a hat, is a frequent cause. Infection seems to play some part. Sebaceous cysts have been seen to develop shortly after an attack of erysipelas. On the other hand, some people possess a congenitally thick skin with extra long ducts to the sebaceous glands, and these might serve from purely anatomical reasons as a cause of retention.

Symptoms.—In form, wens are roundish or somewhat flattened; very rarely do they become pediculated. The hair follicles over their surface atrophy by pressure, so that frequently each sebaceous cyst represents a patch of alopecia. In size they vary greatly. Cooper reported one instance in which the swelling was so large that the hat fitted easily upon it. The smaller ones are usually hard and the large ones soft, even fluctuating. Their number may be very considerable; Poncet removed twenty-two at one séance.

As to their location, it must always be remembered that they lie within, not under, the skin. It can scarcely be possible that a tumor over which the skin is freely movable should be a true cyst. Occasionally they ulcerate, apparently by pressure, through the skin, discharge their contents, and remain as sinuses. Occasionally they become infected and are converted into acute abscesses. Occasionally, again, their walls become calcified.

Diagnosis.—Sebaceous cysts or wens must be distinguished from dermoid cysts and from lipomata. Their recognition, however, is so easy, and the condition so frequent, that the patient himself is always sure of the diagnosis and rarely makes a mistake. The essential point, as already mentioned, is the situation of the wen in the thickness of the epidermis. The dermoid cyst and the lipoma are subcutaneous. The latter, indeed, is frequently subperiosteal.

* Franke: Archiv für klin. Chir., 1902, Bd. 68, Heft 1, p. 126.
† Cushing: Keen's "Surgery," vol. iii., 1908, p. 33.

Over these the skin can always be freely moved. (See also Vol. II, p. 351, et seq.)

Prognosis.—Save in rare cases the outlook is benign. Infection, of course, may occur, and bring with it its own particular danger, a danger, however, which is almost inappreciable upon condition of free incision. On the other hand, in very long-standing cases the cyst may become an epithelioma; this transition I have observed in one of the Royal Victoria Hospital cases.

Treatment.—In the older text-books one finds precise directions for the application of caustics, plasters, etc. Nowadays, however, one hardly needs such inefficient makeshifts, as the tumor may be removed with ease under local anæsthesia and without danger. The skin over the wen should be infiltrated with Schleich's solution, preferably in the shape of a central ellipse, so as to remove unnecessary skin with the tumor. There is no need of cocaine in stronger solution underneath the skin. An incision is carefully made just to the capsule of the growth, and then the cyst may be with fair ease shelled out with the handle of the knife. At its base, if one has not found the best line of cleavage between the capsule and surrounding tissue, a little pain may be caused. At such points the Schleich's solution may be injected, and is effectual. Occasionally the capsule of the cyst has been somewhat thinned by pressure, and one more or less inevitably breaks into it. In such cases the contents had better be immediately expressed, the open edge of the cyst caught with forceps, and dissection proceeded with. This will be a little more difficult than when the cyst is distended by its contents. The important point is always to find the best line of cleavage, and this is always between the immediate cyst wall and the surrounding tissue. One is rather apt not to get close enough to the cyst wall, in the fear of breaking into it and so to lose one's self in the fibrous tissue outside. If the cyst has been shelled out without breaking, the wound may be sutured entirely without drainage. Care must be taken, in making the elliptical incision, to leave sufficient skin for easy and exact closure without tension or redundancy.

d. Dermoid Cysts.—Dermoid cysts represent a developmental fault consisting in the inclusion of epidermal cells during growth; they are therefore congenital. Consequently they make their appearance in early life, usually within the first few years, but also at any time up to puberty. While they may occur in almost any part of the body, they are especially frequent in the region of the head, and particularly so over the frontal area. One favorite spot is at the outer corner of the supra-orbital region, either outside, or, as I have seen, inside the orbit. They are also seen in the neighboring temporal region; and Kroenlein reports a case of an hour-glass dermoid, one portion being inside the orbit, the other in the deep temporal tissues, the two connected by a narrow opening in the outer wall of the orbit. Dermoid cysts are not infrequent at the inner angle of the eye, where they have been described, when small, as accessory caruncles. They are also found in the middle line, especially at the root of the nose. Chipault, in a collection of thirty-one cases, found twenty near the large fontanelle, four in the region of the small fontanelle, and seven over the mastoid process. von Bergmann thinks that those found in or about the orbit represent probably an inclusion of the ectoderm, as it normally occurs in the development of the lens; while those about the mastoid region represent the same for the *Anlage* of the labyrinth.

Anatomically, dermoid cysts represent a sac consisting of fibrous tissue lined internally by the epidermis in various stages of development, and in many cases filled with contents of epidermal origin, fatty detritus, nails, hair, and, very rarely, bone. Sometimes the contents consist merely of serous fluid.

Their situation is always under the skin; not infrequently they lie deeper than the subcutaneous tissue and under the occipito-frontalis muscle. Quite often they are found under the pericranium, and there, by their pressure, prevent the growth of bone; indeed, they may induce reabsorption of bone already formed, so much so that occasionally the bone is quite destroyed, the cyst resting directly upon the dura.

Diagnosis.—Their differentiation from sebaceous tumors has already been indicated. They need also to be distinguished from cephaloceles. In these the important point is their situation. Cephaloceles are hardly ever found over the fontanelle or in the mastoid region; yet over the forehead, especially in the middle line at the glabella, or at the inner angle of the eye, confusion is quite possible. Usually, of course, the cephalocele may be made to disappear by pressure, the fluid retreating inside the skull. Where, as sometimes happens, this is not possible by reason of a cutting off of the intracranial communication, diagnosis may be extremely difficult. An x-ray photograph may be of assistance in revealing the defect in the bone which often accompanies cephalocele. The latter appears usually either at or soon after birth, while dermoid cysts affect the later periods of childhood.

Treatment.—This naturally consists in excision. Care is necessary, with those dermoids which are situated underneath the pericranium, lest atrophy of the bone may have occurred and the dura lie immediately against the wall of the cyst. In large orbital dermoids it may be necessary to resect temporarily the outer wall of the orbit after Kroenlein's method.

II. Benign Neoplasms.—*Lipomata.*—Fatty tumors of the scalp are rare. Grosch's large statistics concerning lipoma in general gave 13 out of 685 as being situated on the head.* Chipault was able to collect 54 instances from the literature.† The forehead is their favorite site, and of Chipault's 54 cases 37 were situated here.

von Bergmann was the first to discover that these lipomata lie, not sub-

* Grosch: "Ueber das Lipom der Schädeldecke." Deut. Z. f. Chir., Bd. 26, 1887, p. 308.
† Chipault: "Travaux de Neurologie Chir.," 1895. Tome i., p. 79.

cutaneously, as one would naturally expect, but underneath the occipito-frontalis aponeurosis and adherent to the pericranium. This, being later confirmed by Grosch, Chipault, and himself, was found to be a regular event. The tumors are sessile and roundish; very rarely may they become pediculated. The skin over them is unchanged. Owing to their deep situation, they are ordinarily not movable to any extent. Their growth is slow. From dermoid cysts their differentiation is sometimes difficult; but the latter tumors, being of congenital origin, usually appear much earlier than the fatty growths. The deep situation of the tumor will distinguish it from an atheromatous cyst. The treatment consists only in excision.

Fibroma.—These tumors are extremely rare. Cushing reports one case from Halsted's clinic. The tumor was very hard, and sat upon the scalp like a tam-o'shanter.

Elephantiasis Nervorum of the Scalp.—This manifestation of von Recklinghausen's disease* has been lately discussed more or less fully by Delfosse (Thèse de Lille, 1904) and by Adrian;† also by Helmholtz and Cushing (*Amer. Jour. Med. Sciences*, September, 1906). Various names have been given to the condition, such as elephantiasis mollis (Virchow), plexiform neuroma (Verneuil), fibroma molluscum, and various others. Its incidence in the scalp was first described by Valentine Mott in 1854, who called it pachydermatocele.

Fig. 1.—Dissection of the Nerve Trunks of the Plexiform Neuroma Shown in Fig. 2. (Chipault, "État Actuel" etc., vol. i., p. 509. Case of Ramakers and Vincent.)

Pathologically it consists essentially of a fibrous thickening of the perineural connective tissue and also of the endoneurium. Inasmuch as this thickening involves the nerves only at certain points in their course, the ultimate result is a series of nodules or fusiform swellings, through which run the nerve trunks

* von Recklinghausen: "Ueber die multiplen Fibrome der Haut," Berlin, 1882.

† Adrian: "Die multiple Neurofibromatose." Centralbl. f. d. Grenzgebiete der Medizin und Chirurgie, 1903, vi., p. 81.

in a more or less open network. A number of these nodes may be quite large. A good illustration of the condition is seen in Fig. 1, which represents a case of Ramakers and Vincent (Chipault, "État Actuel," etc., Vol. I., p. 508). The appearance clinically before removal is seen in Fig. 2. There has been much discussion as to whether the nerve fibres proper in these swellings are increased in amount or not; in other words, as to whether the process is a true or a false neuroma. The new growth of fibrous tissue is undoubted. The nerve fibres, however, so far as one can judge from the histological description of cases, are by no means always increased in number. When they are, they form a regular tangle enclosed in a fibrous matrix, and the whole lies in a large bed of loose areolar tissue, from which the plexus of neuromata may be easily dissected out. As to etiology, the condition would seem to be congenital and sometimes hereditary. It appears usually before the age of twenty; is situated by preference in the fronto-temporal region, occasionally in the parietal or occipital region. In Billroth's case it was bilateral and overlapped the eyes.

Fig. 2.—Plexiform Neuroma of the Occipital Region. (From Chipault, "État Actuel," etc., vol. i., p. 508. Case of Ramakers and Vincent.)

On the clinical side a history of injury is frequently obtained. The growth, at first small, slowly increases in size, and becomes sessile, pendulous, ridgy, and ultimately lobulated, or even pediculated, so that it hangs down like a flap, and may sometimes cover the greater part of the face. Though usually remaining quite benign, it may undergo, in rare instances, sarcomatous degeneration. It is not often painful, but patients seek operation for cosmetic reasons. It is a rare form of tumor. Helmholtz and Cushing report thirty-five cases besides their own; Delfosse collected eighty-eight.

An interesting point concerns the relation of plexiform neuroma, and generally of von Recklinghausen's disease, to multiple fibro-sarcomatosis of the central and peripheral nervous systems. Hulst would make the latter include the former, and adopts the name of multiple fibro-sarcomatosis for the whole. In this view, the usual cerebello-pontine angle tumor becomes intimately related to the plexiform neuroma, both being the expression, sometimes solitary, sometimes but one of multiple lesions, of a fibromatosis or fibro-sarcomatosis of the nervous system.

Treatment.—Removal with the knife is advised. The operation would be simple were it not for the more or less frequent danger of hemorrhage from numerous new-formed vessels in the substance of the tumor. Its ridgy, furrowed surface, moreover, favors the development of an intertrigo eczema, so that cleansing is difficult and infection of the wound to be feared. It is practically never necessary to go deeper than the subcutaneous tissue in its removal.

Adenomata of the sebaceous and of the sweat glands have been described as small nodules, rarely exceeding the size of a pea, and lying under the intact skin. For a more detailed description we may refer the reader to Vol. II., p. 349.

Endotheliomata have also been described. Their histological diagnosis, however, is still somewhat unclear, and their clinical diagnosis is rarely to be made.

Vascular Tumors.—a. Hæmangioma Simplex (Nævus Vasculosus).—The simple vascular capillary nævus in its various forms is not infrequent in the scalp and forehead, especially the latter. Its size varies greatly, although it is usually small. It is sometimes elevated above the surface, sometimes subcutaneous; but more often it lies flat in the epidermis. Its appearance is so well known that it hardly needs description. Being nearly always congenital, it is found chiefly in children. The small, port-wine mark will often disappear spontaneously after preliminary slight increase in size. Sometimes, however, it will grow on until it assumes the hypertrophic form of the simple hæmangioma. When situated over the fontanelles, it not infrequently communicates with the longitudinal sinus, a condition which is not at all apparent on the surface. In rare instances, when it is situated, as it is apt to be, at the root of the nose, it may be confounded with cephalocele. The swelling in either case may be small; but the blue shimmer of underlying veins will differentiate many of the nævi. If, however, the latter lies deeply and its vessels are of the hypertrophic variety, it may be quite impossible to make a sure diagnosis. One's ability to reduce the swelling by pressure counts equally for both. As to treatment, the tumor should be excised if small enough. Otherwise, it may gradually be removed by successive applications of mild caustics, such as nitrous acid, or by electrolysis.

Baerensprung has called attention to the fact that vascular nævi are apt to occupy definite areas which correspond roughly to the skin supply of the various branches of the fifth nerve; and Cushing has suggested that they are the expression of some prenatal affection of the sensory nerves, possibly of their dorsal root ganglia (Gasserian), analogous to the lesions seen in herpes zoster. It has been observed, moreover, that in children showing these trigeminal nævi there often develops a spastic hemiplegia; and Cushing* has further suggested that the underlying cause of this is a coincident nævoid growth in the dura mater leading to intracranial hemorrhage during early life. He reports three cases, in two of which operation was performed for epileptic symptoms. In one of these the procedure had to be abandoned because of enormous bleeding from the bone; in the other, after a preliminary ligation of the external carotid, he separated meningeal adhesions, doubtless the result of old hemorrhage at the age of ten months, and obtained very great improvement.

* Cushing: Jour. Amer Med. Assoc., July 21st, 1906, p. 178.

b. Cirsoid Aneurism (Angioma Arteriale Racemosum).—This peculiar condition, the origin of which is still unknown, consists in an overgrowth of the vessels forming any given arterial tree, for instance, the temporal or the occipital artery and its branches. It is probable that new arteries are formed; but, in any case, it would seem that the arterioles become gradually enlarged and thickened so as ultimately to reach the size not only of large arteries, but even tenfold that which is normal to the particular region involved. They are also lengthened, and so become tortuous. The ultimate picture suggests, to put it briefly, an arterial varicocele. The tumor has the vermiform feel of a packet of veins, and the arterial characteristics of pulsation and often of thrill. It is conceivable that a partial explanation of its origin may lie in Carrel's demonstration that when veins are obliged to carry arterial blood and support arterial pressure, they become thickened and dilated to the size of arteries. One might imagine that the starting-point of a cirsoid aneurism was a small unnoticed arterio-venous aneurism.

FIG. 3.—Cirsoid Aneurism of Parieto-occipital Region. (Dr. Shepherd's case, Montreal General Hospital.)

Pathologically, trauma has been incriminated, especially contusion; but Lexer believes it to be a fault of development, and therefore congenital. This supposition gains weight in view of the frequency with which it has been observed to start in a superficial vascular nævus. Its onset and its growth are usually gradual.

In situation, it involves most frequently the temporal artery, then the frontal; more rarely, as in the illustration here reproduced (Fig. 3), the parietal and occipital. The skin over it is not materially thinned; yet occasionally it may be so; and then a telangiectatic condition of the superficial capillaries shows through as purple flecks. The pulsation and the bruit are the most marked signs; and it is characteristic of these, in contradistinction to the aneurisms, that they cannot be obliterated by pressure. Their growth is frequently rapid at a given stage, after which it usually becomes arrested, and the process remains stationary. The danger associated with it is that of rupture of the thinned skin and fatal bleeding; indeed, this is the usual cause of death, and in itself justifies operation. The diagnosis is sufficiently indicated by the symptoms described.

Treatment.—In the past, when at all extensive, these cases have been considered as somewhat of a *noli me tangere.* They used to be attacked by caustics, which frequently caused secondary hemorrhage and death; by the injection of clotting solutions, such as the perchloride of iron or absolute alcohol, the danger of which lay in thrombosis and embolism; and by prolonged compression. All of these methods proved quite useless; fortunate was the surgeon when they caused no harm.* Nowadays it is recognized that clean removal with the scalpel is the only way to treat them successfully;† and in the less extensive cases this has been attended with a fair degree of success. The danger, of course, lies in the difficulty of controlling hemorrhage, and that can hardly be overestimated. Where a tourniquet can be applied around the pedicle of the growth, the danger is naturally much less; yet in many instances the mass of trunk vessels is situated so low in the temporal or occipital region as to render this impossible. That even the most extensive condition, nevertheless, can be successfully removed is proven by the case of Clairmont.‡ In this instance the arterial overgrowth involved practically the whole of the scalp behind the coronal suture on both sides. Clairmont operated without tourniquet, his only precaution being to advance step by step, ligating all vessels as he met them. After an incision which extended from the fronto-temporal region on one side to the mastoid on the other, the whole scalp was turned back somewhat after the autopsy fashion, and then left for a few days, the rest of the growth being removed by working from underneath at a second stage. This last was accomplished much more easily by reason of the delay, which had given time for thrombosis to develop in the vessels and for a reactionary œdema to form between tumor and skin. The principle underlying this mode of procedure was first laid down by Krause in the treatment of these growths. To Krause also is due the credit of proposing the loosening of skin and tumor together from the underlying parts in one flap in order subsequently to peel off or shell out the mass of vessels from the overlying skin, and then to restore the flap to its normal position. This procedure is also recommended by Koerte. Ali Krogius § has also lately described a method of treatment by subcutaneous ligature, as originally suggested by Beck, which has the advantage of being a comparatively safe operation. He ligates the entire periphery of the growth, and leaves it at that, the tumor going on to atrophy. It should be mentioned

* Siegmund: "Zur Behandlung des Angioma Racemosum." Deut. Zeit. f. klin. Chir., Bd. 37, p. 236.

† Heine: Prager Vierteljahrsschrift für praktische Heilkunde, 1869.

‡ Clairmont, in Arch. für klin. Chir., 1908, Feb.

§ Ali Krogius, in Centralblatt f. Chir., 1905, No. 39.

that in some cases the growth is connected with the deep vessels underneath the occipito-frontalis muscle and probably with intracranial vessels by emissary arteries. Here such peripheral ligation would be useless.

In some instances also there has been found at autopsy a coincident cirsoid aneurism that involved the pia alone or extended as well into the brain substance, and that manifested itself during life in epileptiform symptoms. Such, by the way, were present in Clairmont's patient. In Kalischer's case* such a condition coincided with a trigeminal nævus, an analogon to the coincidence of trigeminal with dural nævus described by Baerensprung. The result was excellent.

III. Malignant Neoplasms.—*Epithelioma.*—It is extremely rare for an epithelioma of the squamous-celled type to develop in the scalp where there has been no very clear evidence of long-continued previous irritation. One sees it, therefore, gradually arise in suppurating wens, in the persistent ulcers of lupus, or on the base of a chronic eczema, instances of all of which the author has seen. Occasionally the starting-point may be a wart, a scar, or a keloid. The accompanying illustration pictures an advanced case of epithelioma which originated in the site of a chronic lupus of many years' duration. (Fig. 4.)

Fig. 4.—Epithelioma of the Scalp, Grafted upon a Lupus of Many Years' Standing. (Dr. Shepherd's case, Montreal General Hospital.)

Histologically these tumors present certain varieties of growth which have long been difficult to classify. Krompecher's division into the basocellular, spino-cellular, and cubo-cellular forms, based upon their assumed origin from the cells of the three layers of the epidermis, is now more or less widely accepted. Yet this is a matter chiefly of histological interest; what it imports to know is that any one of them may result in a cancerous ulcer with raised, indurated edges, with whose appearance we are so familiar, made up of a zone of central destruction with a periphery

* Kalischer: Berl. klin. Woch., 1897, p. 1059.

of proliferation. Neglected cases of this sort present ultimately a horrible picture of deep destruction, involving not alone the superficial parts, but also the bone beneath, the dura mater, and the brain itself. At times, however, the dura seems to form an efficient barrier, as was the case in the patient whose condition is illustrated in Fig. 5. Here, in spite of vast bony destruction, the cerebrum remained protected by the overlying dura, although deeply compressed.

The only proper treatment is wide excision. The author has seen practically no benefit from *x*-ray treatment; on the contrary, while the superficial ulcer

FIG. 5.—Malignant Disease, Primary in the Skin, Destroying the Roof of Right Orbit and the Right Fronto-parietal Region of the Skull, and Causing Cerebral Compression, but without Destruction of the Dura. Note the extensive destruction of bone by epithelioma. (From the McGill Pathological Museum, No. 91, 69, 1.)

has at times shown evidence of healing, the subcutaneous growth has spread widely and formed distant metastases. Gland involvement must be looked for in the retromaxillary fossa, deep behind the angle of the jaw, behind the ear, or in the post-cervical triangle.

Sarcoma.—In the scalp sarcoma is usually primary, rarely metastatic. It may be situated either in the skin or in the subcutaneous tissues. In the former case it has somewhat of a papillomatous appearance; in the latter, that of a firm subcutaneous swelling. It is unnecessary here to describe the histological structure, which is sufficiently well known.

The papillomatous variety offers a good prognosis, while the contrary is true of the subcutaneous tumors. Occasionally these are of the melanotic type; and then, of course, the outlook is practically hopeless. In certain instances a sarcoma may take on angiomatous growth, and may then show pulsation; such tumors have been mistaken for aneurism. In a patient who came under the observation of the writer this was particularly evident.

The subcutaneous tumors have to be distinguished from tuberculous or luetic granulomata. This will frequently be difficult; yet the concomitant signs of these two diseases are usually present to assist in the diagnosis, and in no long time they declare themselves plainly by the ordinary process of breaking down.

Treatment.—Where it can be determined that the lesion is solitary, wide excision is the only course. Neither exposure to the x-rays nor the use of Coley's serum has accomplished anything, in the writer's experience.

Traumatic Affections of the Blood-Vessels of the Scalp.—SIMPLE ANEURISM.—But few words need be given to this condition. Its spontaneous occurrence is rare; nearly always its causation is found in trauma. From the pathological standpoint, it is a "false" aneurism. Its diagnosis will hardly ever cause difficulty, as it presents the typical signs of aneurism elsewhere, and lies so superficially as to be unmistakable. As to treatment, simple ligation, in view of the very free anastomosis of vessels of the scalp, is quite insufficient; and one must resort to complete extirpation, a procedure which is of easy performance. I have had occasion to see but one instance of this lesion in the Royal Victoria Hospital. It involved the occipital artery; ligation of the external carotid was followed by no more than temporary improvement.

ARTERIO-VENOUS ANEURISM.—This pathological condition presupposes trauma as its cause. In the days of frequent venesection an arterio-venous aneurism in the temporal region was a frequent event. Cushing reports a case where the occipital artery and vein were involved; he notes that the veins distal to the site of the communication had become greatly thickened and dilated, so that they conveyed the arterial thrill and became quite prominent in the scalp. One is reminded of Carrel's experiments in the reversal of the circulation, in which he observed, after the lapse of some time, a thickening of the vein which had been joined to the artery of such extent as to represent practically an arterial wall. Such a process of thickening may, naturally enough, spread and involve new venous trunks, and thus the whole may in time come to occupy a considerable area. The treatment consists in operative extirpation of the communication, with ligature of both vessels, proximal and distal.

Gangrene of the Scalp.—Gangrene may affect the scalp in badly nourished children; and the lesion then is frequently spreading and fatal, somewhat after the fashion of noma in the cheek. Its starting-point is usually a localized area of pressure; its spread is certainly due to bacterial action.

Neuralgic Affections of the Scalp.—Hyperæsthesia in certain fields is seen as the expression of local inflammation of the dura, presumably in consonance with the work of Mackenzie and with that of Head upon referred pain. It is really doubtful, however, whether the dura can be incriminated always; in man this membrane, at least when uninflamed, has been shown by Heidenhain and by Cushing to be non-sensitive. We have learned to look for hyperæsthesia of the occipital and upper cervical regions in cases of gunshot wound of the brain, and even in cases of fracture of the skull and cerebral laceration. Of this, more in another chapter.

Post-zoster neuralgia, with which one is familiar in the case of the intercostal nerves, is also seen not infrequently in the scalp, especially in the supra-orbital territory; and is accounted for pathologically by microscopical lesions of the Gasserian ganglion (Howard, quoted by Cushing) similar to those found in posterior-root ganglia in the intercostal form. As Cushing and others say, such neuralgias are usually intractable, and are to be cured only by an extirpation of the Gasserian ganglion or the cutting of its sensory root.

The affections of the fifth as well as the other cranial nerves are discussed elsewhere in this work. (See the article on Surgery of the Cranial Nerves, in the present volume.)

The Infectious Granulomata.—Syphilis of the Scalp.—The essential nature of the reaction of the tissues to Schaudinn's Spirocheta is the production of a new tissue which consists mostly of small round cells and, to a less degree, of endothelioid proliferation. A similar reaction of course may be seen as a result of many other kinds of infection; but the later course, the degree of proliferation, of necrosis, and of demarcation, as well as other peculiarities, lend especial character to the syphilitic process and distinguish it from granulomata due to other causes.

In the early stages of syphilis this small-round-cell infiltration happens to take on the form of a more or less diffuse infiltration, while in the later stages it is apt to grow in the globular form called gumma, although no distinct line of demarcation in many cases can be drawn. In a general way the tendency of the former is to become reabsorbed and replaced by fibrous tissue; the tendency of the latter is for the centre to die, caseate, be reabsorbed if of small extent, and extruded if of large. In either case, while the centre dies the periphery responds to irritation by proliferation. The ultimate result is a mass of fibrosis, which may long persist unchanged, or be ultimately reabsorbed, leaving but a very small scar.

In the late secondary or in the tertiary stages it is not an uncommon experience to observe gummata in the scalp situated most often in the frontal region, less often in the parietal. These are often multiple, and are apt to be grouped. Their appearance is the well-known one of granuloma, shining bluish-red through the distended skin. Their size is very variable, and they are apt to ulcerate and to be serpiginous in outline. Under treatment they heal easily, but at the cost of radiating or irregular scars which are quite pathognomonic.

It is hardly necessary to elaborate in the matter of diagnosis. On general principles the majority of granulomatous tumors in adults situated on the forehead or over the parietal region are luetic. Tuberculosis, actinomycosis, glanders, etc., originating in the scalp, are very rarely found in this situation. I have seen in the occipital region a granuloma due to glanders break down and ulcerate; but it almost certainly began in the cranial diploë. Tuberculous swellings in the scalp are not seldom seen, particularly in children; but they usually have a deep origin in the bone.

II. THE CRANIAL BONES.

Disturbances in the Growth of the Cranial Bones.—It is hardly necessary in a work of this character to do more than mention the various dystrophies that affect the cranium, whether of atrophy or of hypertrophy, inasmuch as the majority possess no surgical bearing beyond their occasional implication in differential diagnosis. They have in the main purely a pathological interest.

Cranial Atrophy.—Atrophy is seen as a result of pressure; normally, for instance, in the pits on the internal surface of the skull in which lodge the Pacchionian bodies; pathologically, in the case of tumor—although here the atrophy of pressure is ordinarily combined with the destructive effect of the tumor cell. In old men there occurs the so-called senile atrophy, the cause of which is quite unknown. Its lesions occupy symmetrical positions, but they are patchy, and the atrophic process may even go so far as to cause actual defects.

The craniotabes of rickets is largely the result of pressure combined with the pathological condition of the bony structure. Thus it is found chiefly as an atrophy of the parieto-occipital region where the head rests upon the pillow. In the frontal region it is characteristic for the opposite condition to occur, and the overgrowth of the frontal bones results in the well-known large square head of rickets. This same condition of craniotabes is seen in the very heavy head of congenital hydrocephalus.

That obscure fœtal dystrophy affecting the osseous system which bears the name of osteogenesis imperfecta,* and which, as Losser † has shown, is identical with idiopathic fragilitas ossium, represents a congenital fault in bone development which leads pathologically to excessive osteoporosis and thinning of the compact cortex; there seems to be nothing more definite than these changes. Not infrequently the atrophy results in fracture of the bones in utero. As a part of the disease an extreme lack of cranial development may be found. Where the patients survive for any length of time there may occur considerable deformity of the cranium from irregular growth. I owe to Dr. Klotz, of Montreal, the opportunity of examining a case of the fœtal disease.

* Simmons: Annals of Surgery, August, 1907.

† Losser: Mittheilungen aus d. Grenzgeb. d. Med. u. Chir., Bd. 15, p. 161.

The subjects of the malady usually die early; but, if adult life be ultimately attained after a somewhat unfortunate career characterized by multiple fractures, there becomes evident a tendency to spontaneous cure.

Cranial Hypertrophy.—There will be considered here only those hypertrophies which appear to depend upon systemic disease, while the local conditions resulting from infections and from tumor formation will be considered apart. Of the systemic conditions the chief are: acromegaly, gigantism, leontiasis ossea, and lastly the osteitis deformans of Paget. The last two, however, are now considered to be probably identical.

Osteomalacia need here hardly be considered, inasmuch as the cranium is involved in none but the severest cases, and has then no surgical interest.

Acromegaly.—In Vol. III. of this system, p. 340, Roswell Park has admirably described the lesions found in acromegaly, as well of the head as of the rest of the body; and the reader may be referred to his article. Yet in consideration of recent views as to its etiological connection with affections of the hypophysis, it is necessary in this place to consider the matter in this aspect. The facts that it has been possible to remove tumors of the hypophysis with success, and that the patients suffering from acromegaly are often great sufferers from headache, bring the matter well into the practical domain of surgery. The question will be discussed in greater detail in the section on Cerebral Tumors. At this point it is only necessary to touch upon the question of the connection of hypophyseal tumors with acromegaly.

The earlier assertions to the effect that the disease was uniformly due to some derangement of hypophyseal function, whatever that might be, by tumor, hypertrophy, cyst, or sclerosis of the gland, founded though they were on sound observation, have since been shown to be incorrect for at least a considerable number of cases. Cagnetto has lately come to the conclusion that the theory which declares that a close connection exists between the two is erroneous, inasmuch as he has found acromegaly present without any disturbance of the glandular portion of the hypophysis, and inasmuch as, on the other hand, there occur hypophyseal adenomata containing numerous functionating cells without the existence of acromegaly. In a patient from whom Sir Victor Horsley had removed a tumor of the hypophysis, and whom the writer had the opportunity of observing while at Queen's Square Hospital, ten months after operation, it could not be said that acromegaly had been or was then present.

Diffuse Hyperostosis of the Cranial Bones (Leontiasis Ossea).—This very puzzling overgrowth of bone, so classically described by Virchow, seems to have been first noticed by Malpighi in 1697, and one of its typical examples is well known to every visitor to the Musée Dupuytren in Paris. In the essentials the disease process consists in a diffuse enlargement of the cranial bones and the jaws, an enlargement which may attain extraordinary proportions. There exists a rarer form in which, in addition to the hypertrophy, there are present circumscribed exostoses sitting, as it were, upon the areas of diffuse overgrowth.

Etiology and Pathology.—The etiology of the disease is quite unknown, though trauma and erysipelas have been vaguely incriminated. Lues can be quite excluded. It is probably a congenital anomaly.

As regards the pathological alterations, there is present a diffuse sclerosis of the bone; yet not infrequently there goes with this, underneath the eburnated exterior, a very definite process of porosis, the one or the other predominating in different specimens. In two cases (Bassoe,* Ziegler) the diffuse form has been found in combination with gigantism. Not infrequently one finds this last condition associated with the localized form. Bockenheimer † has lately published an extensive article upon the disease, and in this he furnishes résumés of twenty-five cases that have been reported and clinically observed. He himself had seen five cases in twenty years. He believes that the term "leontiasis" should be dropped, and that that of "diffuse hyperostosis of the bones of the cranium and of the face" or "osteitis deformans fibrosa" (Paget) ‡ should be adopted.

The disease is very insidious in its onset. It begins usually in the frontal bones or in the upper jaw and spreads in all directions, its course being extremely slow. As a mechanical result of overgrowth there occur obstructions to the various adjoining cavities, the nose, the orbit, and the cranium. The nares may finally become quite obstructed and the eye is protruded, so that ultimately one may see develop symptoms of cerebral compression from the ubiquitous contraction of the cranial space. As a matter of fact, the patients die, in many cases, of cerebral compression. They are apt to suffer much from pressure on branches of the fifth nerve. Bockenheimer considers the process as identical with Paget's osteitis deformans fibrosa.

Diagnosis.—A slowly progressive enlargement of bone beginning in the frontal region or in the superior maxilla and advancing diffusely without symptoms of inflammation must always suggest very strongly this condition. In acromegaly, bony enlargement always begins in the epiphysis of the long bones, and only later involves the face. The hyperostosis of lues is not so uniform nor so extensive, and there are confirmatory signs of the specific disease elsewhere. A skiagram is important in early diagnosis.

Treatment.—No medical treatment seems to have ever accomplished anything. The disease has been attacked surgically on several occasions. In 1895 Horsley § reported 5 cases in 3 of which an operation was performed. Bar-

* Bassoe: "Gigantism and Leontiasis Ossea." Jour. of Nervous and Mental Disease, 1903, vol. xxx., p. 513.

† Bockenheimer: Arch. f. klin. Chir., Bd. 85, H. 2, 1908.

‡ Paget: "On a Form of Chronic Infl. of Bones (Ost. deformans)." Med.-Chir. Trans., London, 1877, vol. xl., p. 37.

§ Horsley: Practitioner, vol. lv., p. 12.

denheuer* removed the jaw in 2 cases. Such interference has been justified in some of the cases by neuralgia due to pressure; in some apparently it has been done without other object than that of removing the deformity. In view of the progressive and diffuse character of the disease, surgical interference can hardly be justified, save for pain.

GIGANTISM.—This condition can hardly be said to interest the surgeon in any particular way except in so far as it occasionally seems to be a generalized expression of an osteitis deformans, and as such may present in its earlier stages localized overgrowths of the frontal or maxillary bones, just as in Virchow's leontiasis ossea, — overgrowths which may necessitate palliative operations for the relief of pain.

FIG. 6.—Osteoma of the Left Frontal Sinus, Extending Backward through Meninges and Destroying Left Prefrontal Lobe. The appearance of the brain and the tumor is shown in Fig. 7. This photograph was taken in Feb., 1901, four years before the patient's death. (Case of Dr. Buller and Dr. Bell.) Note the orbital swelling and the displacement downward and outward of the eyeball.

Parasitic Cysts. — The only parasite that attacks cranial bones with any frequency is the Tænia echinococcus. Gangolphe † has collected fifty-two cases from the literature, of which four involved the skull. The cysts were all unilocular; their development was very slow, and frequently began in childhood.

New Growths of the Skull.—OSTEOMA.—Here, as elsewhere, one meets with exostosis springing from the periosteum and enostosis in the diploë, and with the eburnated, the compact, or the spongy form of new growth according to the consistency of the tissue. The osteoma arising in fibrous tissue is the rule; the chondral form is practically absent in the skull, as so little of the cranial structure is laid down in cartilage.

In shape the cranial osteoma may be rounded, oval, or quite irregular; or it may rise from the skull like a mushroom; and the surface, though usually smooth, is often, too, quite nodular. In size it is for the most part comparatively small, but may be very large; in situation it is usually either frontal or parietal.

* Bardenheuer: "Deutsche med. Woch.," 1906, Bd. 32, p. 1518.

† Gangolphe: "Kystes Hydatiques des Os." Thèse de Paris, 1886. Consult further, von Eiselsberg: Arch. f. klin. Chir., Bd. 81, H. 1, second case.—Putnam: "Hyperostosis Cranii." American Journ. Med. Sc., 1896, p. 12.

Not infrequently it grows from the inner aspect of the skull. It is usually solitary, but occasionally multiple, as in Virchow's well-known text-book illustration.

Osteomata arising in the accessory cavities of the cranium demand separate consideration. A favorite region is within the frontal sinus, the growth origi-

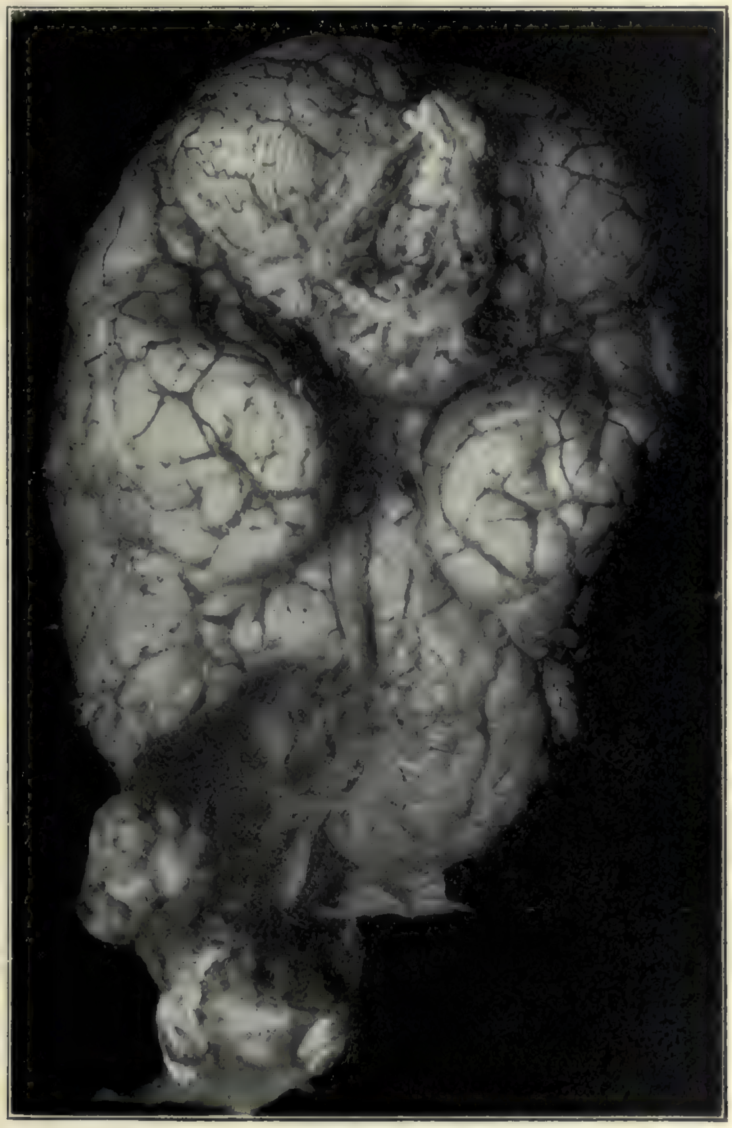


Fig. 7.—Osteoma Originating in the Left Frontal Sinus, with Growth Backward through the Meninges, and Destruction by Compression of a Large Portion of the Left Frontal Lobe. (See Fig. 6.) In the photograph the tumor is turned forward from its bed in order to show depression in the brain. Anteriorly remain attached portions of the dura mater and spicules of the frontal sinus. (From the Path. Dept. of the Royal Victoria Hospital, No. 15, 1905.)

nating in its periosteum; less often they grow in the sphenoidal sinus or from the ethmoid cells. In all these situations they become, as it were, encapsulated.

The most frequent and most important form is the frontal-sinus osteoma, which usually consists of a compact external layer enclosing spongy cancellous tissue. In their growth these tumors break through, usually toward the forehead and into the orbit, less often into the nares or the cranial cavity.

Symptoms.—Ordinarily there appears first a swelling over one frontal sinus, or at the inner angle of the eye. Growth is very slow, but ultimately the orbit becomes invaded and the eyeball is pushed downward and outward, vision naturally becoming affected. When the tumor grows chiefly toward the cranium, one may get the evidence of increased pressure upon the frontal lobes in headache, intellectual deterioration, and epileptiform convulsions. Suppuration frequently accompanies the growth, which is comprehensible enough when one considers its origin in a cavity so exposed to outside infection. Thus the course of the growth is apt to be interrupted by attacks of frontal sinusitis and to end in a meningitis. The accompanying figures (6 and 7) illustrate the conditions in a patient who was operated upon by the late Dr. Buller in 1901, and who ultimately died, in 1905, of recurrence complicated by cerebral abscess.

L. R. [Ophthalmological Case Reports, Royal Victoria Hospital], aged 17. Admitted March 26th, 1900. In October, 1899, he had been knocked down by a car. and the left side of the head was bruised. In January, 1900, he noticed that his hat did not fit well, and that the pressure of it on the left side of the forehead caused slight pain. Shortly afterward a small, hard, and slightly tender nodule was noticed above the left eyebrow. Then came on giddiness with staggering, and stabbing pain felt in the region of the nodule and in the back of the left eye, while the nodule increased greatly in size. On the 31st of March Dr. Buller, by morcellement, removed the growth, which filled the frontal sinus and had broken through into the orbit. There was a compact external covering with pulpy cancellous interior. It was surrounded by pus. A sinus persisted for years in spite of several curettings. Later, nearly continuous headache developed; sight failed in the left eye; the patient became stupid, irritable, and intemperate. A year after the operation there began epileptic fits without focal character, which continued at intervals up to a few months before the patient's death in March, 1905. He died with symptoms of cerebral compression which lasted over two weeks and were due doubtless to the secondary infection of a congenital cyst of the right frontal lobe, causing abscess, as well as to the osteoma. At the autopsy the recurrence was seen to have grown chiefly toward the cranial cavity. Histologically it was quite benign.

Diagnosis.—The diagnosis is not difficult where deformity exists. It is made from the slow and painless increase in size, which differentiates the lesion from the more rapidly growing sarcoma on the one hand, and from painful inflammatory affections on the other. If the exostosis is situated on the internal aspect of the cranium, it can only be guessed at when cerebral symptoms develop. If it is situated in the sphenoidal sinus, it usually affects sight early by pressure on the optic nerves. An *x*-ray photograph, as lately pointed out by Perthes, is of great value, both in diagnosing the fact and in estimating the operability of the tumor.

Treatment.—Radical removal of such a tumor is an atypical operation. Though benign, the growth may recur if not completely removed. Thorough exposure, therefore, is required. An incision should be made along the eyebrow, and to this should be added a vertical one in the middle line. The anterior wall of the sinus is then to be removed with the chisel, and, if necessary, the roof of the orbit also. One will then usually find a line of separation between the osteoma and the wall of the sinus; and with the aid of an elevator the growth may be pried out; or, if this fail, the tumor may be removed by morcellement. It is occasionally necessary to remove the posterior wall and expose the dura

FIG. 8.—Sarcoma of Frontal Bone, with Ulcerating Surface. (Dr. Shepherd's case, Montreal General Hospital.)

before getting it all out. The operation is often difficult, and the danger of sepsis is not small, inasmuch as both frontal and nasal cavities are opened, and pus is frequently already present. In Chipault's collection of 15 cases in which the osteoma involved the cavum cranii, 5 recovered and 10 died, the latter usually of meningitis or abscess. I have myself seen cerebral abscess develop subsequently to opening of the frontal sinus, with the dura intact, in apparently a perfectly clean case. More recent statistics show a much-reduced mortality.*

* For further details see: Bornhaupt: "Ein Fall von linkseitigem Stirnhöhlenosteom." Arch. f. klin. Chir., 1881, Bd. xxvi., p. 589.—von Eiselsberg: "Zur Casuistik der knöchernen Tumoren des Schädeldaches." Arch. f. klin. Chir., 1907, Bd. lxxxi., p. 1.

Sarcoma.—Sarcomata in the cranial bones do not differ pathologically from those found in the rest of the bony system. They arise either in the diploë or in the periosteum, internal or external. A good example of a periosteal sarcoma is seen in the accompanying illustration. (Fig. 8.) Tumors of this kind are either round- or spindle-celled in type; while those of the myelogenous variety, which arise in the diploë, consist histologically of either round or spindle cells mixed with giant cells. As to situation, Weisswange found in his series that twenty-three arose in the periosteum, forty from the diploë.*

Not infrequently the growth takes on the characters of an osteal sarcoma, in which form the new production of bone may be enormous. The extraordinary degree to which the skull may become thickened in these cases of osteo-sarcoma is well illustrated by Fig. 9. The process represents probably an irritative effect upon the bone-forming elements of the dura and the bone itself. In other cases the sarcoma becomes angiomatous. One instance of this has come under my notice in which the growth evidently began in the diploë—possibly from the dura,—broke through externally, and appeared in the temporal region as a pulsating soft tumor, over the surface of which could be felt isolated fragments of bone.

Fig. 9.—Osteo-sarcoma, the Origin of which Remained Doubtful, Whether in Meninges or Cranium; causing in any event secondary enormous overgrowth of the calvarium, combined with areas of bone destruction. (Dr. Armstrong's case, Montreal General Hospital.)

Symptoms. — Symptoms will vary with the site of origin. A tumor starting in the dura mater, like any other intracranial growth, at first causes obscure cerebral symptoms. The tendency, however, of dural sarcoma seems to be rather to break through the bone externally than to involve brain substance, although of course it may grow in both directions. In these cases there will be deep headache combined with symptoms referable to the portion of brain compressed. Ultimately the skull is perforated by the growth, and a roundish or oval swelling is formed underneath the aponeurosis, which for some time opposes a barrier to its exit. With time, however, it breaks through the scalp and becomes a fungoid, bleed-

* "Beitrag zur Lehre von den primären Sarkomen des Schädels." Freiburger Dissert., 1897.

ing, ulcerated tumor, which, in spite of its foulness, is welcomed by the patient for the relief it brings from the headache. It is, in fact, a spontaneous decompression. An instance of this nature has been kindly communicated to me by Dr. Parizeau, of the Nôtre Dame Hospital in this city.

The symptoms of tumors arising in the diploë are represented chiefly by the occurrence of deep pain and slight tenderness, with the gradual development of a tumor. Those beginning in the pericranium are not usually painful, and of course present themselves first as external swellings comparatively early.

Diagnosis.—The diagnosis of the nature of these growths is at first frequently difficult; indeed, it can rarely be made before the swelling appears externally. The tumor must then be distinguished from the granulomatous infections of syphilis and tuberculosis; and such a differentiation is rendered possible only by the course of the disease, and by a consideration of the history and coincident lesions elsewhere. Sarcoma in the skull may of course be secondary to the primary disease elsewhere. The writer has seen it follow a sarcoma of the calf muscles in a child of three years; and in this instance it was situated in the diploë. The cranium is sometimes invaded by sarcoma arising outside it; for instance, in the orbit, of which the writer has seen a case; or in the upper jaw. One is sometimes unpleasantly surprised, in removing a sarcoma of the upper jaw, to find that it has invaded the base of the skull through the spheno-maxillary fissure or the sphenoidal sinus. The incidence of trigeminal neuralgia in such patients should warn one of the probable compression of the Gasserian ganglion by just such extension upward; of this also I have seen an instance.

The sarcoma which arises in the dura can at first be recognized only as a cerebral growth of one sort or another. After perforation and the appearance of the mass externally it is a frequent mistake to leave its intracranial origin unsuspected. With overproduction of bone, as in the osteo-sarcomata, a skiagram will sometimes assist the diagnosis. Any bony tumor of the cranium must be differentiated from that peculiar generalized affection of the bony system called myeloma (Kahler's disease). In other words, it is necessary in every case to examine carefully the whole osseous system for the evidence of other myelogenous tumors. If such are found, and if there is no evidence of tumor in any other part of the body outside of the bony system, and if the urine contains the Bence-Jones body (albumose), a diagnosis of myeloma is justified.

Prognosis and Treatment.—Metastases are common in the lungs and rare in the lymph nodes; yet this remark applies only to the round- and spindle-celled forms. For many years it has been recognized that the myelogenous form with its giant cells is but slightly malignant; Nélaton, indeed, used to deny its malignancy altogether. This fact is of importance in the question of operation. It is probable that the principles established by the late von Mikulicz, and later confirmed by the analyses of Bloodgood, with regard to sarcomata of the long bones, to the effect that amputation was useless, and that a conservative resection was sufficient in nearly all cases, are also quite justified in sarcomata of the cranial bones. In fact, if the tumor be of the spindle- or round-celled variety, a wide local removal will be as effectual as an amputation (speaking of the long bones), inasmuch as, if metastases are to occur, they will almost always be already present; if they have not occurred, the more conservative operation is sufficient; while in the myelogenous variety, which rarely forms metastases, local wide removal is quite sufficient. These views, applied to the sarcomata of the cranium, justify a wide removal of the bone in all cases in which the disease is not too far advanced. Gruenberg* investigated the after-history of seventeen such instances, and found that fifteen remained cured. The prognosis in those which began in the pericranium is perhaps better than when the disease originates in the bone or the dura, because of its earlier diagnosis.

The operation itself is apt to be very bloody, and great care is indicated in controlling hemorrhage. Ransohoff † lost one case from this cause alone, the bleeding being due to extraordinary dilatation of the diploëtic veins.

Myeloma.—Myeloma is a form of tumor characterized by the development of multiple growths which are confined to the bony system and develop in the medullary spaces. The cell structure is lymphoid in character, the individual cells being of medium size, round, and with large nuclei. They do not affect the periosteum, and never form metastases outside of the bones themselves. The cranium may be very extensively destroyed when the disease affects that part of the osseous system.

Pathological fractures are common. Diagnosis may occasionally be made, before the tumors make their appearance externally, by the discovery in the urine of the Bence-Jones body, an albumose. Jellinek‡ has recently reported a case and has given the subject full discussion. No instance of the disease has come under the writer's observation.

Carcinoma.—Carcinoma affecting the bones of the skull can occur only as a metastasis or by invasion from the scalp. In the case of a metastasis, the treatment is hopeless; if the disease represents merely an extension, a wide removal of bone with the scalp is to be advised. The diagnosis offers no material difficulty.

Osteomyelitis of the Cranial Bones.—That acute inflammation of bone which is due to the pyogenic cocci, and which we are accustomed to call simple osteomyelitis, occurs infrequently in the flat as compared with the pipe bones, and infrequently in those of the cranium as compared with other flat bones. In 131 cases of osteomyelitis affecting the latter, the cranium was involved in only twelve instances. § Nevertheless, the analogies with the same disease in the long bones are clear enough. Thus, the foci of infection may be single or mul-

* "Zwei Fälle von perfor. Sarkom des Schädels." Greifswalder Dissert., 1897.

† Trans. Amer. Surg. Society, 1904.

‡ Jellinek: Virchow's Archiv, Bd. 177, 1904, p. 96.

§ Froehner and A. von Bergmann: St. Petersburg. med. Woch., 1884, p. 37.

tiple. As with the long bones, so here one may frequently find a number of foci separated by healthy bone; and in the cranium, these foci are usually found in different bones. It is more especially an affection of youth, and the term osteomyelitis adolescentium is as applicable here as elsewhere. In onset and early course it reveals the same characters, and it goes on in a similar fashion either to early death or to a chronic stage of sequestra, abscess, or pyæmia.

Etiology.—Etiologically, the familiar coincidence of a local injury and an evident source of infection, the blow on the head with the furuncle on the skin, is not infrequent. Yet often neither of these factors can be discovered. Very frequently the disease seems to be a direct extension from a frontal- or mastoid-sinus infection. (Schilling.)

Symptoms.—The symptoms begin with severe headache, and the illness is occasionally mistaken for the onset of a tuberculous meningitis. The suddenness, however, and the severity of the pain, together with the early and marked rise of temperature, soon suffice to prevent this mistake. The situation of the pain will vary with the location of the infection. There will be deep tenderness without at first any evidence in the overlying scalp; on the second or third day, however, the latter will become swollen and red, and the diagnosis of a deep infection is therewith established. The subsequent course is like that of osteomyelitis elsewhere, with the one notable exception which depends upon the anatomical neighborhood of the brain and its coverings. In one case it may go on to early death from generalized infection, while in another it may pass on into the so-called chronic stage, in which those areas of bone which have been killed by the acuteness of the inflammation become gradually sequestered, while abscess forms and breaks through into the soft parts. This stage may be complicated by a septicæmia or pyæmia of chronic type. What is peculiar, however, to the osteomyelitis in these bones is the great tendency toward infection of the dura mater or the lepto-meninges, even of the brain mass itself, by way of an infective thrombosis starting in the emissary veins of the diploë and extending inward. In this appears a striking contrast with the infectious granulomata (tuberculosis, syphilis, glanders), to which the dura usually offers an effective barrier; while, on the other hand, it presents a striking similarity to the later course of mastoid infections. Keimer* reports an interesting instance of the acute disease, the source of infection being apparently a furuncle over the right temple. The route of infection lay along the periorbital veins into the diploë of the frontal bone; and the infection ultimately involved the frontal, right temporal, and right occipital bones. Early and free incisions on the second day evacuated the pus and apparently saved life.

In the records of the Royal Victoria Hospital† I find an instructive case of this nature:

* Keimer: Deutsche med. Woch., July 11th, 1907, p. 1131.

† Royal Victoria Hospital: Book 8, p. 93, Service of Dr. James Bell.

A man, aged 37, after severe exposure, was taken with chill, fever, and generalized pain through the body. There followed severe headache and in the course of two or three weeks an abscess in the frontal region, the evacuation of which failed to relieve the headache. Shortly delirium supervened, and was more or less continuous for nearly three months, at which time metastatic abscesses developed in the right wrist and the left thigh. The patient having been brought to hospital at this stage, two small sinuses in the forehead were widely opened, carious bone removed, and the dura found inflamed. The incision of the latter revealed an intradural abscess, which was drained, with ultimate recovery.

The occurrence here of early and long-persisting cerebral symptoms is instructive as illustrating the tendency to the formation of abscess within or without the dura.

Diagnosis.—The diagnosis is made without difficulty from the history and the local signs, and is confirmed, at the first evacuation of pus, by a bacteriological examination.

Prognosis.—The prognosis is usually bad; not only because of the well-known danger of such acute infections in bone, but more particularly because of the local involvement of the cerebral membranes.

Treatment.—The indication is clear: free incision as early as possible. With the sudden onset, acute localized tenderness, and fever, one should incise down to the bone; and, if the infection be not clearly confined to the soft parts, the bone should be trephined down to the diploë without waiting for the evidence of redness and swelling in the scalp. At a later stage, when the danger of the onset is apparently over, one may perhaps wait till the presumed sequestrum is separated, usually a matter of several weeks. But, in view of the danger of intracranial extension, it would be wiser to explore thoroughly the depth of the abscess or sinus in the scalp, and to trephine freely so as to expose the whole area of diseased bone; even though the disease seemed to be confined to the diploë. It is better to remove the inner table also, inasmuch as an abscess may lie between it and the dura, or even, as in the case above reported, beneath the dura.

Cranial Syphilis.—Acquired Form of the Disease.—The syphilitic virus may attack the cranium at any period of the disease, save the primary, yet most often during the tertiary stage; and it may settle first either in the periosteum or in the diploë of the bone. In either case it often extends and involves the other. Gummata are, of course, characteristic of late syphilis, and the diffuse, flat infiltration causing an inflammatory process of simpler type belongs rather to early syphilis. Yet the one passes insensibly into the other; and the variations are mainly those of degree. It is unnecessary to relate here in detail the gross and minute pathology of bone syphilis as it manifests itself in the cranum. (See Vol. III., p. 364.) Suffice it to say that, as elsewhere, the essentials of the process are made up of destruction with proliferation. The one results in osteoporosis, caries, or gross necrosis; the other, in osteosclerosis, eburnation, hyperostosis, all according to the acuteness or chronicity, the extent and the virulence, of the infection and the resistance of the individual.

In the periosteum this effect is seen in its two extremes as the bony overgrowth of the syphilitic node and as the acute breaking-down gumma which perforates the skin. In the bone itself the exudate begins in and extends along

Fig. 10.—Very Extensive Syphilitic Lesion of the Skull. Note the combination of necrosis with reactive osteogenic processes, producing the worm-eaten appearance. (From the McGill Pathological Museum, No. 91, 53, 9.)

the fibro-vascular tissue of the Haversian canals, taking its origin in the diploë. The effect of the granulation tissue is to bring about resaborption of the bone, so that the Haversian canals are widened. When this process extends to the surface, or, beginning in periosteum, extends from the surface inward, the bone is seen by the naked eye to be traversed by numerous foramina, and presents a worm-eaten or honeycombed appearance, like close-set gopher-holes in a miniature prairie. This represents the slighter degrees. It is a microscopical canalicular necrosis. The more intense reactions cause necrosis in mass. The result clinically is sequestrum formation, in which the sequestrum may be of almost any size. At times the process affects the bone in a circle, as in a patient whose history will be given later; at times the sequestrum is of altogether irregular shape, or is patchy, areas of necrosis being strewn irregularly between areas of sclerosed or healthy bone. The sequestrum may be enormous—witness the illustrations here reproduced from specimens in the McGill Museum. (Figs. 10, 11, and 12.)

Short of a large mass (necrosis with sequestrum, circular or otherwise), we find the most irregular lines combined with the smaller, circular or irregularly shaped areas of destruction, each being bounded by its rampart of new bone. The ultimate picture is the most worm-eaten, honeycombed skull imaginable—

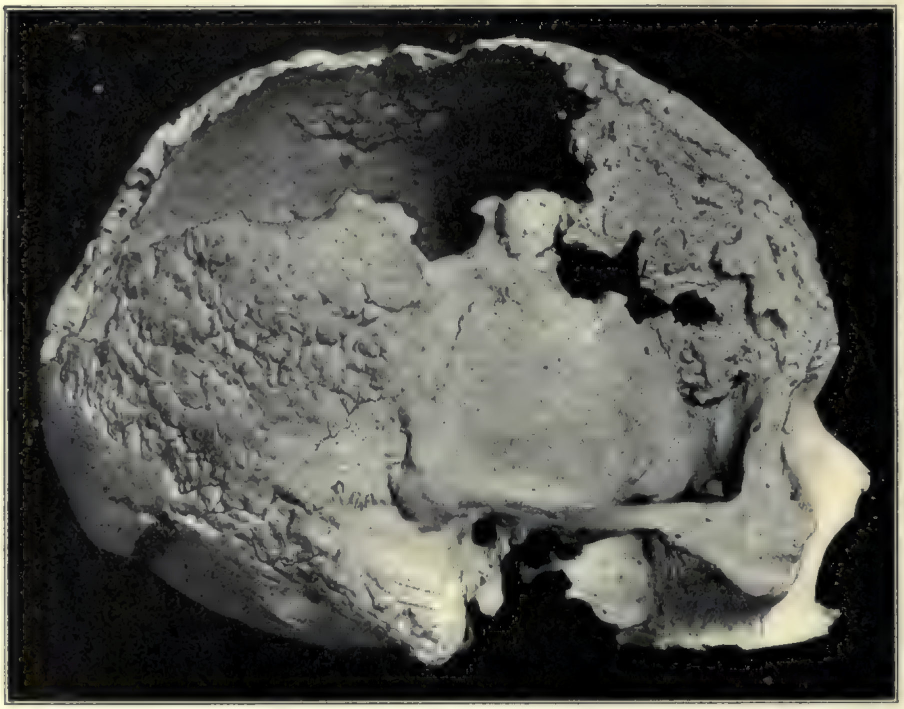


Fig. 11.—Side View of Skull Shown in Fig. 10. Note the enormous area of total necrosis. (From the McGill Pathological Museum, No. 91, 53, 9.)

furrows in all directions, with hollows and depressions of all shapes, mixed with ridges, mounds, and nodules of new bone of all sizes. And the process may spread over the whole vault. The base, curiously enough, is very rarely affected, probably because it lacks a diploë. Jaffredon* reports several instances of sphenoidal involvement. The extreme grades are rarely seen on this side of the Atlantic and in this generation; and textbook illustrations, including those here reproduced, are of the older specimens in the museums. Our people are better fed and more thoroughly treated than of old. On the other hand, the extreme

* Jaffredon: Thèse de Bordeaux, 1897.

thickening of reactive proliferation is well shown in a specimen in our museum, already reproduced by Professor Nicholls on page 162 of Volume I. I am able to picture also an instance of a large circular sequestrum, in this instance in the frontal bone. (Fig. 13.) Here the dead bone was of a dull yellowish-white color, and was perforated by a number of enlarged foramina, the dilated Haversian canals. It was considerably sclerosed, in places eburnated.

Such widespread lesions represent the rarer event. Ordinarily syphilis is evidenced in the cranium by a single gumma, situated most frequently in the frontal bone. Sometimes there are several isolated gummata, as in the

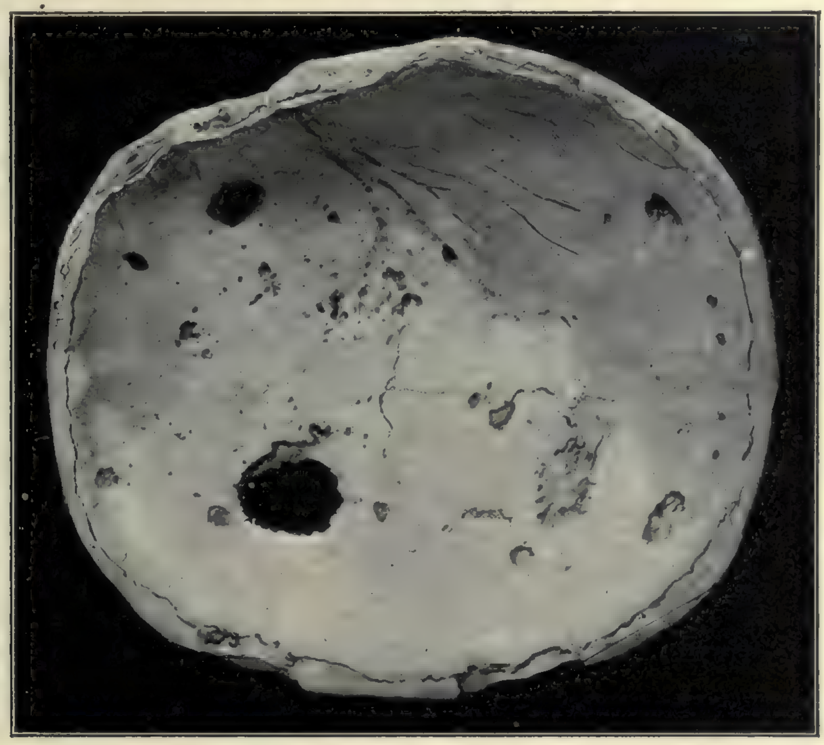


Fig. 12. — **Multiple Areas of Syphilitic Ostitis of Skull, Leading in Several Places to Necrosis of the Whole Thickness and to Perforation. (From the McGill Pathological Museum, 91, 53, 12.)**

skull pictured in Fig. 12. The periosteum is probably more often the primary site than is the bone diploë. In the latter case perforation toward the dura mater is very likely to occur, and this membrane becomes covered with foul granulations, a *pachymeningitis syphilitica externa.* Inasmuch as, under these circumstances, perforation in the contrary direction, through the skin, usually happens simultaneously, there is afforded free escape for the products of destruction; and an actual break through the dura, with involvement of the brain, is very rarely seen.

Congenital Cranial Syphilis.—Congenital cranial syphilis is practically never seen in the early stage. When it does occur, it is a manifestation of *lues hereditaria tarda*, in children that have weathered the early years; and it then differs in no material particulars from the process in the acquired disease. Darier and Foulard (I quote from von Bergmann) observed a very extensive gummatous formation in the skull of a child of eleven months, in whom syphilis had first appeared in the fourth month. In a man of twenty-one I have observed very extensive congenital syphilitic necrosis, which first caused ulceration at the age of eighteen, with sequestra so extensive as to require removal of the greater part of one parietal bone.*

Symptoms and Diagnosis.—The symptoms of the disease, in contrast with this rather striking pathological picture, are upon the whole slight and ill-defined. Pain, swelling, and breaking down characterize the acute process, whether periosteal or osteal. In the chronic cases, when a gumma grows first in the diploë, I have observed the persistence of deep, unexplained headache for weeks and months before involvement of the periosteum and soft parts betrayed the true nature of the trouble. Yet pain may be lacking, and swelling form the chief, wellnigh the only, symptom; and, when the bone alone is affected, even this may fail.

The firmly elastic tumor of a periosteal gumma, with its inflammatory signs, can hardly be confounded with anything but a granuloma caused by some other disease, usually tuberculosis. In one well-remembered instance I have seen chronic glanders imitate it strikingly; but that is a rarity of the first order. From tuberculosis the history, the age incidence,—early in the one, later in the other,—the character of possible coincident lesions, and the therapeutic test will suffice to distinguish it.

The acute periosteal or osteal gumma causes rather severe deep boring pain, worse at night, a symptom rarely observed in tuberculosis. The gumma that grows slowly will frequently cause no pain at all. Fenger † was surprised once to find at autopsy extreme osteoporosis in the clavicle of a patient whom he had watched throughout her disease, and who had never complained of pain in that region. Even the extensive process of destruction and repair, as described above, may run a very chronic course without more liquefaction of tissue than can be reabsorbed *pari passu*, and therefore without any evident objective signs; while, correspondingly, the subjective signs will frequently be surprisingly mild, no more, for instance, than deep, dull pain in the bone, especially at night. Such pain is often mistaken for rheumatism. The cranial gumma, in cases of tardy hereditary lues, particularly those in which no clear history is obtainable, may be confounded with an osteosarcoma; and, indeed, operation has been done under this error in diagnosis. Fortunately, coincident lesions elsewhere usually guard one against such a mistake. From this and other

* Royal Victoria Hosp. Surg. Case Reports, No. 11,519, Service of Dr. James Bell.

† "Die Syphilis und die venerischen Krankheiten." Franz Deuticke, Leipzig und Wien.

mistakes our chief protection lies in a careful history, a search for the frequently present and more characteristic lesions in other parts of the body, and in the typical, punched-out appearance of the ulcer when the lesion has gone on to that condition.

Treatment.—In the eyes of the internist the knife has no place in the therapeutics of syphilis. And in the main the proposition is true. Yet there are circumstances, not at all exceptional—for instance, the acute suppurating gumma—in which surgery can be of decided help; and there are others, such as the big imprisoned sequestrum, in which no amount of mercury or the iodides can replace it. Syphilis is a definite infection due to a known organism, and, like other infections, liable to spread if the products of its action upon tissues be kept under tension. It is not alone a systemic invasion; it is also a local infection, with foci from which fresh infection may be transported into the surrounding tissues. I believe that this danger is sufficient to justify those surgical measures which are applicable in other infections, where and whenever specific drug treatment proves itself either too slow or too weak in its effect. In this sense the indications, speaking summarily, are to give free exit to retained pus or caseous exudate that resists absorption, and to remove sequestra that are not easily or early extruded by natural means.

The acute periostitis of the secondary or early tertiary stage will ordinarily subside rapidly under treatment; exceptionally it persists or involves a larger area; and especially is this the case with the later, more pronouncedly gummatous exudates. When such a mass does not within from ten to fourteeen days of treatment show signs of subsidence and reabsorption, it will be quite justifiable, even advisable, to incise and curette freely with the object of shortening and limiting the process.

Another form which, as a rule, gives no indication for operative interference, is the diffuse, widespread gummatous process in the bone, which runs a very chronic course, characterized by molecular necrosis and neighboring repair without gross collections of luetic pus. It is difficult to conceive how surgery could in such conditions do good; and specific medication is usually sufficient. Yet if, in the course of time, such an area should come to contain small sequestra and numerous minute discrete collections of pus, bridged over and retained by new osteophytic tissue, then a great deal of good can be done by free exposure of the area and a thorough curetting or chiselling away of the obstructing osteophytes, together with the sequestra and the caseous and purulent detritus. This is a purely secondary condition for which mercury and the iodides can do but little; and the free drainage thus secured may be the one thing necessary.

The acute breaking down of a gumma gives a clear indication for early incision.

In the presence of sequestra operation is clearly indicated. The worst instances of this sort are those in which an extensive and acute infection beginning in the diploë kills the bone over a large area, breaks through the periosteum on the one side, forms in the soft parts a large gumma, which later penetrates the skin, attacks the dura mater on the other side, and produces a chronic pachymeningitis.

The removal of the sequestra in such patients is a purely surgical problem. In size these vary greatly. Hofmeister* records an instance in which the gap left after extraction of the dead bone measured nearly five inches each way. In a case belonging to the service of Dr. James Bell, in the Royal Victoria Hospital, which I observed nearly nine years ago, a very large part of the right parietal bone was removed in the course of repeated operations extending over a year and a half. Three years ago I had occasion to remove a circular sequestrum from the frontal bone which occupied nearly the whole forehead and measured three and a half by two and a half inches (*vide* Fig. 13). And all text-books give illustrations comparable with the one here reproduced from the McGill Museum, showing the enormous destruction possible. (See also Karjewski's case in Chipault, "État Actuel," Vol. II., page 102, and Llobet's, Vol. III., page 836; in the last, particularly, the whole vertex was destroyed.)

FIG. 13.—Extensive Syphilitic Necrosis of the Frontal Bone, with Destruction of the Overlying Soft Parts. The whole area of bone, to the extent shown and also slightly beyond, under the skin edge, was necrotic. (Author's case.)

Unlike the sequestrum of the staphylococcus osteomyelitis, which dies *in toto* and is in no long time completely separated from living tissue, the necrotic process in lues is apt to be slow, hesitating, as it were, patchy, and incomplete. The dead tissue passes insensibly into the living, and the lapse even of months will not suffice to draw a clean-cut line of demarcation between the two. Add to this the fact that the reparative process shoves in its bars and ledges of new bone over, around, and between the patches of necrosis, and that frequently the inner table is less involved than the outer, or contrariwise, and one can understand the difficulty that opposes the efforts of Nature, and indeed those of the surgeon

* Hofmeister: von Bruns Beiträge, Bd. 13, p. 453.

too, to free the living tissue from the dead. These facts make it evident also that it is useless to wait long weeks or months after the discovery of dead bone in anticipation of a complete line of demarcation. It is better to interfere early.

For all these reasons the operation is a somewhat atypical one. The ulcer represents usually but a part of the total area of dead bone, which extends more or less widely under its edges. The general outline of the sequestrum will be distinguishable enough; but the chisel or saw will have to be used freely in cutting through bridges of eburnated bone. The inner table is sometimes much better preserved than the outer, and care must be taken not to sacrifice it needlessly. On the other hand, the dura may be thickened and covered with luetic granulations for some distance underneath the edge of a healthy inner table; and it is wise to open up such recesses by removal of bone. The healthy bone bounding the sequestrum is frequently so sclerosed as to be eburnated, and consequently possesses no abundant circulation. It is, therefore, of importance, in making the exposure preliminary to the removal of the sequestrum, not to push back the pericranium from this edge of eburnated bone; else one will deprive it of its already precarious blood supply and induce further necrosis.

Fig. 14.—Case of Extensive Syphilitic Necrosis of the Frontal Bone. (The same case as that shown in Fig. 13). Transplantation of flap from forearm. The photograph shows the result nearly two years later. The scar which remains, and which is due to some suppuration at the edges, shows more unfavorably in the photograph than in the living subject. It is, however, successfully concealed, except the corner between the eyes, by a "front" of false hair. (Author's case.)

When the sequestrum removed is large and is frontal in site, and when the skin over it has been extensively ulcerated, it becomes an important question how to repair the defect so as to get a reasonably good cosmetic result. In the writer's case,* referred to above, the defect, after removal of a large oval sequestrum, measured three and a half inches transversely by two and a half vertically. This was repaired by means of a flap raised from the anterior surface of the left forearm, with the pedicle at the bend of the elbow. The accompanying photographs show the condition before and after operation. (Figs. 13 and 14.)

* Archibald: Montreal Medical Journal, January, 1906.

Tuberculosis of the Cranium.—The localization of the tuberculous process in the flat bones of the cranium, as in the case of other flat bones, is rather rare. It is true that a fair number of cases are reported from English and European clinics: yet these figures hardly apply to conditions on this side of the Atlantic, and the difference represents probably no more than the contrast between an old country more or less permeated by tuberculosis and a young country as yet comparatively free from it. In the fourteen years during which the Royal Victoria Hospital has been in existence, there has occurred no instance, so far as I can find, of tuberculosis of the skull; and I have had but one case in private practice. The mastoid process forms an exception to the rule. This bone is not infrequently affected; and, as is emphasized more particularly in late reports, may be so even in the infant. The writer has lately had occasion to observe, in consultation with Dr. Jamieson, an example of this condition, ultimately complicated by meningitis, in a child of five months. In one instance, in private practice, I have seen the disease confined to the roof of the orbit, a short distance behind the external angular process. The lesion is found most often in children and young adults below the age of twenty. In not a few instances it occurs also between the ages of twenty and thirty, but after that it becomes rare, yet may be seen up to the age of fifty or over.

Pathological Anatomy.—The affection usually begins in the diploë, rarely in the periosteum. As to locality, the frontal bone is the one by far the most frequently affected; next, the parietal, and then the occipital. In rare instances the base of the skull has been found diseased. (Stockert, *Beitr. z. Klinik d. Tuberculose,* Vol. V., No. 4.)

One may distinguish two forms. In the first the trouble is more or less localized, and is very apt to perforate the external and internal tables and to give rise to collections of broken-down tuberculous material or cold abscesses both within and without the cranium. This is the more frequent condition, and, in fact, German and French authors consider it to be the typical form. In the second, the spread of the tuberculous process takes place rather in the substance of the diploë, extending in all directions and giving rise to a diffuse caseating infiltration which usually perforates the bone in both directions at certain spots, and results in the formation of sinuses in the scalp. The extent to which this process may spread is sometimes extreme. Stanley Boyd (*Brit. Med. Jour.*, 1898, I., p. 495) reports an instance in which, to quote his own language, "the frontal bone was everywhere worm-eaten, and perforated in several places, and contained sequestra"; he was obliged to remove "the greater part of the squama of the frontal bone, the orbital arches, and a large portion of the orbital plate. The dura was exposed and was covered with opaque yellow material in laminæ." Mr. Shield (*Brit. Med. Jour.*, 1898, I., p. 495) has also reported a case in which the occipital bone was similarly affected, and was removed almost entire in a boy of six years. Gaudier and Bachmann (*Echo Méd. du Nord,* July

24th, 1904, quoted in *Centralbl. f. Chir.*, 1904, p. 1426) resected in a boy of ten years almost the whole squamous and parietal bones and half of the left frontal, evidently a case of diffuse caseous infiltration. The large skin flap was resutured, two or three drains were inserted, and primary healing was obtained.

The tendency of tuberculosis in bone is here, as elsewhere, to cause destruction rather than proliferation: in other words, to result in the formation of cold abscesses rather than in osteosclerosis or hyperostosis; and, in these respects, it differs markedly from the lesions caused by lues or the pyogenic cocci. Sequestra, when formed, are usually small; they become, in the course of time, well delimited from the healthy bone, and are therefore easily removed. Still, when this molecular caries is sufficiently widespread it results in the production of quite large defects in the cranium, approaching in size those seen as the result of lues. Occasionally the tuberculous process may be confined to the periosteum, and may then form a small, roundish mass, closely resembling gumma.

When the inner table is perforated, a cold abscess frequently develops between the cranium and the dura. The latter becomes covered with tuberculous granulations and is considerably thickened; yet, practically always, it acts as a very efficient barrier to any extension into the brain. When in such cases a tuberculous meningitis develops, it is found to be an independent lesion. Such cold abscesses between the cranium and dura may attain no inconsiderable size. Thus, in a case reported by Sawici (Chipault, "État Actuel," etc., Vol. II., p. 418), a pocket of pus measured 4 by 5.5 cm.; in another reported by Doellinger (Chipault, Vol. II., p. 512) it measured 12 by 6 cm., and depressed the brain mass 2 cm. In this last case, remarkable to say, there were no cerebral symptoms, and the child was cured in three months.

Symptoms.—The symptoms are those natural to the pathological manifestations of the disease, and correspond to its primary situation in the diploë. One usually finds that the patient first complains of a deep-seated headache, the pain incidental to all chronic affections of bone. This may be very slight. When it grows severe, one must expect to find a perforation of the inner table and pressure upon the dura. After a certain lapse of time, an abscess usually forms externally, breaks through the skin, and leaves persistent sinuses in the scalp. Rarely do we find a coincidence of cerebral symptoms. An interesting case, however, in which such were present, was reported by Chipault (Chipault, "État Actuel," Vol. I., p. 192) where the process had resulted in a localized pachymeningitis without giving rise to any external lesion. Jacksonian epilepsy going on into general crises had been present from the age of nine; ultimately at the age of sixteen there had resulted hemiplegia, followed by hemicontracture and athetosis. At operation a focus of tuberculous granulations arising in the diploë and perforating the inner table alone was found present upon the dura. Its removal brought about cure within a few months, with complete disappearance of all hemiplegic symptoms.

Prognosis.—This will depend naturally upon the local extent of the disease, upon the presence of tuberculosis elsewhere, and upon the nature of the treatment. In a general way, as Clemen showed in the statistics of Koenig's cases,* the outlook is good if the disease is confined to the cranium, and is gloomy when it forms no more than part of a generalized affection. The danger of meningitis, as already said, does not depend upon the contiguity of the leptomeninges to the cranial focus, but rather upon the presence or absence of generalized infection. The writer had occasion lately to operate upon an infant of seven months which, after undergoing five weeks previously the radical mastoid operation for tuberculous lesion, had developed a hemiplegia. The operation demonstrated an entire lack, so far as could be seen, of any continuity of infection from the mastoid to the leptomeninges. The infection was, as shown by the subsequent autopsy, chiefly basal, and there was a tuberculous nodule in the pulvinar, accounting sufficiently for the hemiplegia. Reber (*Jahrbuch f. Kinderheilkunde*, Vol. LXV., p. 202; ref. *J. A. M. A.*, April 13th, 1907) has lately reported 24 cases in children. Of these, 9 were cured permanently by operation. In 5 there were left large depressions in the bone. In 1 the defect had been completely filled in. Mild cases healed without local treatment, others required puncture of abscesses and the injection of iodoform emulsion; while the more extensive ones demanded resection of bone. In all the fatal cases there were found multiple tuberculous foci, indicating that the cranial disease was merely part of a general process. The same condition was discovered in 61 of 105 cases reported in the literature.

Treatment.—That general rule in the surgical treatment of tuberculosis which advises eradication of the disease where possible and where function can be sufficiently preserved, applies also here; and such eradication is usually possible in the case of the cranium. Witness the cases of Boyd, Shield, and others, in which large portions of the skull were removed. The operation, of course, is an atypical one, and consists in the following up of sinuses and the removal of diseased bone, by means of the trephine and rongeur forceps, well into healthy tissue, without regard to the extent of the lesion. von Bergmann is of the opinion that the bone defects thus caused are regularly filled in; and, indeed, that this excellence of repair is more or less peculiar to localized skull tuberculosis. One may reasonably believe that it is due rather to the fact that the skull is in the growing state. Tuberculosis is, in fact, the only granulomatous lesion that attacks in a particular way the skull of the child. There will not infrequently occur the necessity for repeated operations, and especially is this the case in the diffuse caseous infiltration of the diploë. In operating, one may entirely neglect any consideration which has to do with the wideness of the

* Koenig: "Lehrbuch der speciellen Chir.," 1898, Bd. i., p. 165.

gap left, inasmuch as this will probably be closed in time, provided the dura be left intact. In infants, or generally, where operation is considered inadvisable, the conservative treatment may not infrequently lead to cure; or, let us say, the *vis medicatrix naturæ* will overcome the disease unaided.

Actinomycosis of the Cranium.—The cranium is very rarely affected by the ray fungus. In some twenty odd cases observed during the last eight years at the Royal Victoria Hospital the cranium has not been involved. Terrier and Dujarrier (*Revue de Chir.*, 1906, No. 3) reported an instance in which the tissues of the neck and of the mastoid region were affected, but the bone slightly, if at all. Job (Thèse de Lyon, 1896) reports three cases from Poncet's clinic, in all of which the disease was secondary to a primary lesion in the superior maxilla.

Where the part affected is accessible, an atypical operation will naturally be done, as much of the disease as possible being removed, and this will be combined with the usual treatment by the iodides. The prognosis is very bad.

Glanders of the Cranium.—Dr. Robins (Royal Victoria Hospital Reports, Vol. II., No. 1, "Study of Chronic Glanders in Man, with Report of a Case." Analysis of 156 cases collected from the literature and an appendix of the incidence of equine and human glanders in Canada, May, 1906) has lately reported an instance of chronic glanders in man lasting over two years, and ending fatally. About fourteen months before death, the patient began to be afflicted with severe headache in the occipital region, persisting without material remission for six weeks, at the end of which time there was discovered a granulomatous mass over the occiput. This, being incised, was found to lead through a large perforation in the bone to a second collection lying between the bone and dura and forming a dumbbell-shaped abscess. The contents resembled those of a broken-down gumma. The pus between bone and dura appeared to be inspissated, and was sufficient to cause a considerable depression of the brain, which, however, did not produce cerebral symptoms. The dura had remained intact.

The condition appears to be not so rare as one would *a priori* expect; in fact, a cranial localization seems to be a fairly prominent feature in chronic glanders. Of those which came to autopsy—44 of the 156 cases collected by Robins—11 per cent had local purulent external pachymeningitis secondary to caries of the bone; 13 cases showed abscess in the scalp and forehead. Infection of the osseous system was found in 24 of the 156 cases; and of these 24 the skull was infected 4 times. I am not aware that the cranium has ever been found affected in the acute form of the disease.

The prognosis is necessarily extremely bad, although, according to Robins's figures, 40 of the 156 cases were considered cured at the time of reporting. Many of these certainly died later. Adopting a five-year limit, Robins found in his 156 cases only 2 definite cures. When the cranium is affected it must be considered that the disease is generalized, and in such instances there is small room for hope.

Diagnosis is suggested by the history of the infection from horses, but is only assured by the discovery of the specific bacillus.

TREATMENT.—From the surgical standpoint, treatment consists merely in the incision of abscesses as they develop.

Incised, Contused, and Punctured Wounds of the Skull.—Incised wounds are naturally confined almost entirely to the vault. They will vary, of course, in depth and extent according to the sharpness, the size, and the weight of the instrument. If the bone is completely penetrated, the wound is to be considered as a wedge-shaped fracture. Certain generalities are to be noted. In the first place, the penetration of a sharp instrument into the bone must act as a wedge; yet the sharper the instrument and the finer the blade, the less does this principle come into play. With any deep penetration of a massive weapon, such as a hatchet, one must expect to find fissures running for a variable distance from either end of the wound, and sometimes extending into the base. In the second place, their seriousness depends almost entirely upon the concomitant effect on the brain and the possibility of infection. Rarely will a clean incised wound of the soft parts and cranial bone alone cause danger, and then only from hemorrhage. Koenig relates the case of a man whose occipital artery was cut and who nearly bled to death in consequence. The effect upon the brain will vary with the penetration or non-penetration of the weapon, and with the nature of the wound as well as with the coincident concussion. A very sharp instrument may cut directly into the brain; and unless it wound an area of known function, there may result nothing serious. These matters may be reserved for consideration later.

Contused wounds, inflicted by blunt instruments, are usually complicated by depression of the bone, and are therefore considered fractures. Punctured wounds are also, for the most part, fractures. Short of breaking the bone, these injuries offer no special points of interest apart from what has already been discussed in the section on wounds of the soft parts. As to treatment, the indications are likewise the same. Particular stress must be laid on the necessity of preventing infection by thorough opening of the wound and the removal of foreign material that might cause infection. If such material is found ground into the bone wound, the chisel is to be used. The conduct to be adopted in presence of a punctured fracture is considered in the section on fractures.

Fractures of the Skull.—Peculiar and apart as is the architecture of the cranium in comparison with the rest of the skeleton, and vital as is the nature of the organ that it houses, in no less degree peculiar and apart is the mechanism by which its structure is broken, and no less vital is the importance of the lesion that threatens that organ. These are the two outstanding considerations in the great subject of cranial fractures—the *modus operandi* of their occurrence, and the possible lesion of the underlying brain. The latter of these will be discussed in a separate section. To the former we may immediately address ourselves.

Causation and Mode of Action.—The violence that fractures a skull is usually said to be direct or indirect; direct when the bone is broken at the area of impact; indirect when at a distance from that point. In one sense, however, this definition is incorrect, inasmuch as the skull is always broken by violence attacking the skull itself; and when the solution of continuity is found at a distance from the point of impact, it is the result of a transmission of that violence. In this sense all skull fractures are direct.

The nature of the violence and its mode of application are naturally of endless variety; yet it is hardly necessary to illustrate these in detail. What imports is that certain ground types may be deduced from any large series to represent the manner in which the violence acts. Of these the chief are compression and the blow. The skull may be compressed from two opposite poles; or it may suffer a blow on one side from a swiftly moving object. In the one case predominates the element of slowness, in the other that of rapidity; in the one the violence acts simultaneously from two opposite poles; in the other it acts only from one side. Theoretically, however, unilateral violence can never be purely unilateral when the object that strikes the skull is moving rapidly, because the skull's inertia, resident in its own weight, together with the attachments to the trunk, must always furnish some degree of counter-resistance, and in that sense supply the element of bilateral compression. The more penetrating the object and the smaller its surface of impact, the less will this factor come into play. Practically, also, this principle holds true to a large extent, as will be seen when the question of bursting fractures comes to be discussed. The same is true again in those cases in which the skull is thrown violently against a hard and fixed object. Here the factor of bilateral compression is furnished by the momentum of the "after-coming head" (if the reader will pardon the obstetricality). There is here what the French call "*tassement*," or piling up, of the violence. Likewise in falls upon the vertex, the weight of the after-coming trunk falling upon the occipital condyles affords the same bilateral compression, between the earth and the spinal column. The same is again true, though to a less degree, in falls upon the buttocks, where the violence acts in a contrary direction, but is lessened by the measure of the difference in weight between the head and the trunk. It is evident, therefore, that the principle of bilateral compression, besides filling its own province, is present also in many cases of injury from a blow.

In the second class, violence from a blow, we have to distinguish more or less clearly two sets of circumstances. In the one the wounding surface of the object causing the injury is small and circumscribed, possibly angular or pointed; in the other it is broad, diffuse, and always blunt. Thus, for instance, a hammer in the one case, and a sandbag in the other. It is self-evident that the more the violence is of the former kind, the more will its breaking or its penetrating effect be limited to the locality struck; whereas the more the violence is of the latter sort, the greater will be its diffusion and the greater will be the factor of bilateral compression.

There remain two other types of violence which differ sufficiently from the foregoing to deserve separate mention. These are the splitting action of the wedge, where the element of straight cleavage brings in a new factor; and the explosive action, seen in gunshot wounds. This last, as I conceive it, is, in its essence, similar to that of bilateral compression, but differs in the fact that the compression is exerted from inside the skull outward, and in that it acts more or less equally and simultaneously upon all points of the inner skull surface.

What, then, are the effects produced by these various types of violence? And do the effects produced reveal any regularity of occurrence? Given the conditions of the violence, are we able to predicate the nature and direction of the fracture that may have occurred? In the answer to these questions, I shall endeavor, first, to present the views of Messerer* and von Wahl, now more or less universally accepted, together with the few modifications which they have undergone since their publication; and later to touch more briefly upon various other theories that have been proposed.†

The key to the comprehension of cranial fractures is found in the conception of the skull as an elastic body: elastic in its parts, that is, in its substance; and elastic in its whole, that is, as an ovoid or spheroid. According to Rauber, the cranial bone substance is in itself possessed of a high degree of elasticity. Yet more important than this is that quality which it shares, though in small degree, with a rubber ball. If a skull be dropped from a height upon the floor, it will rebound. The essence of the term "elasticity" lies in this, that the particles of which a given body is made up will, under compression, so rearrange themselves as that the surface will give inward to a certain extent without suffering solution of continuity, and upon release of the compression will immediately reassume their former position so that the surface springs outward again. The degree to which this will occur before the particles suffer solution of continuity, that is, fracture, is in a way the measure of the elasticity of the body. It was the elder von Bruns who first demonstrated this quality in the skull, taken as an approximate sphere, or what we may call a spheroid. Compressing very gradually a fresh cadaver skull in a vise, he was able to demonstrate by exact measurement with a pair of calipers that the diameter joining the two poles of compression was materially reduced before fracture occurred, a diminution varying from 5 to 10 mm. being often observed. At the same time, as a necessary corollary, the two other diameters, transverse and vertical, running at right angles to the diameter of compression, were lengthened. Upon release

* "Experimentelle Untersuchungen über Schädelbrüche," München, 1884.

† In the conviction that a text-book should set forth principles rather than catalogue facts, the writer has ventured upon some degree of detail in presenting this subject.

of compression, the skull's elasticity showed itself in a springing back to the original shape.

These results were later confirmed by Messerer and Hermann. Felizet* took up the question from another side. The elasticity of ivory billiard balls is measured by letting them fall from various heights upon an unelastic floor covered with soot. The extent of the resulting soot-covered area upon the billiard ball is the measure of its elasticity. This procedure was carried out by Felizet with skulls filled with paraffin; and a very decided elasticity was demonstrated. von Bergmann, again, tested the matter by using the principle of distance of rebound. If two elastic spheres suspended in the air be made to swing toward each other from measured distances, the distance of rebound following their violent contact is, *cæteris paribus*, the measure of their elasticity. Comparing in this way skulls with various other bodies, von Bergmann found that the elasticity of the dried skull lay between that of soft wood and that of brass, yet much nearer the latter than the former. It must be added, however, that according to Rauber, the elasticity of the fresh warm skull is slightly less than that of the dried. This is the elasticity of the skull as a whole, regarded as a spheroid. But the bone substance itself, as Rauber showed, is decidedly elastic. A narrowly localized pressure upon any one part will have to force the surface inward to a variable depth before fracture will occur. It is not alone that the normal cohesion of the bone elements resists fracture for a certain time, but also that these elements allow a certain disturbance of their arrangement, subject to an immediate elastic return to the original arrangement, before their cohesion is overcome.

Now it is evident that if a hollow spherical or spheroidal body be compressed beyond the limit of its elasticity, it will necessarily burst at some point or other. This is a fact common to all spheres, whether elastic or not, provided their structure possess a certain degree of cohesion and not too great a degree of ductility. But, in the case of the skull, we find that the form of the resulting fracture is largely dependent on its quality of elasticity. It bursts under compression, yet the gaping cleft is immediately reduced to a mere crack or fissure by the elastic back-spring of the bone edges. This fact has invited comment from many of the classical writers on this subject, and has been adduced as explanation of the observation that frequently hair is found firmly caught in fissures of the bone. All the text-books give space to the mention of the various objects, both extra- and intracranial, that may be found included between the bone edges; and, of these, two or three examples will suffice. Thus, Neudoerfer found in a fissure a piece of the victim's felt hat; Hofmann, a piece of the dura, Friedberg, even the basilar artery; while, most instructive of all, von Bergmann discovered a fragment of ball nearly half the size of a Snider bullet, inside the white substance of the cerebral hemisphere, while the skull showed not the smallest

* "Recherches Anatomiques et Expérimentales sur les Fractures du Crâne," Paris, 1873.

opening. To quote him: "The external surface of the skull shows but one minute break of the external table; yet not the smallest hole is visible, not even after maceration and upon holding up the skull to the light."

Upon this basis of the skull's elasticity, von Wahl * grounded his well-known classification of all cranial fractures, whether of the base or of the vault, into two great divisions, bursting fractures and bending fractures (*Berstungsbrüche* and *Biegungsbrüche*). To understand these, it is necessary to go a little deeper into the details of what happens upon the application of violence to the skull. The result will depend chiefly upon the working of four factors: (1) The degree of the violence; (2) the nature of the violence; (3) the extent of the area of impact; and (4) the degree of the skull's elasticity.

As to the first, it is self-evident that the greater the violence the more certain will be the fracture; and upon the other three we have already touched. We have indicated that, in general, the nature of the violence may be either that of bilateral compression, crushing inward two opposite surfaces of the skull, which is regarded as a sphere; or that of unilateral compression, crushing inward a localized area of the skull, which is regarded as a slightly convex bony surface. In the one it is a question of the laws of physics which concern a hollow, or to all intents and purposes hollow, ball; in the other, of those which concern a flat surface. Clinically the one may be represented by the crushing of a man's head between the buffers of two railroad cars, and the other by the blow of a hammer or of the sharp edge of a rock. That between these two extremes all grades of transition, all possible combinations of the two effects, may and do occur goes without saying.

Bursting Fractures.—Let us consider first the question of pure bilateral compression from any two diametrically opposed poles of the cranial surface. And, following von Wahl, let us picture the skull's sphere as being divided, like a geographical "globe," into parallels of latitude and meridians of longitude. If the two areas of compression be imagined to be the north and the south poles respectively, the parallels of latitude will run parallel with the equator, and their diameters will be at right angles to the diameter joining the two poles; while the meridians of longitude will run parallel to the same diameter, that is, parallel to the direction of the violence. In this sphere there will be three chief diameters, one joining the poles of compression, which may be called for convenience the horizontal, the two others crossing this at right angles, one vertical and one transverse.

Now, the main fact brought out by von Bruns's demonstration of the skull's elasticity was that under compression the horizontal diameter is shortened, and consequently the two others correspondingly lengthened. What effect has this upon the meridians, that is, upon the cranial shell? Let us take an example: Suppose the skull were compressed in the transverse direction from parietal bone

* "Ueber Frakturen der Schädelbasis." Volkmann's Sammlung klin. Vorträge, 1883, No. 228.

to parietal bone. The biparietal diameter will be shortened, and all the axes running at right angles to it will be lengthened, that is, those running from forehead to occiput and from vertex to base. Now, this will mean a corresponding lengthening of the meridians joining the two poles; and the lengthening of the meridians will evidently reach its greatest degree at the equator; that is, the distention of the hollow elastic sphere will be greatest at the equator, which in this case would run in an antero-posterior direction along the longitudinal sinus and the middle of the base of the skull; and the distention will gradually diminish as the compression poles are approached. This is illustrated in the accompanying figure in which the distention clefts are widest at the equator and become gradually narrower toward the poles. Therefore the tendency to separation of the meridians from each other by distention—their disruptive force, as Dulles

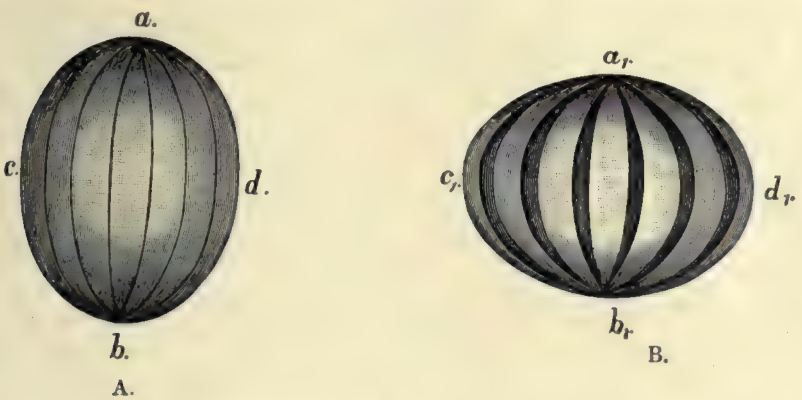


FIG. 15.—*A* Represents a Hollow Ellipsoid, the Shell of which is Divided into a Number of Segments by Meridional Lines between the poles *a* and *b*. *B* represents this ellipsoid when pressure is made on the poles; the diameter *ab* is thus shortened (a_1b_1) while the diameter *cd* is elongated (c_1d_1). The meridional segments, the edges of which were originally in apposition, are, as a natural consequence of the change of form, separated from one another by gaping slits, widest at the equator and decreasing evenly toward each pole. (Ali Krogius, *Deut. Zeit. f. Chir.*, Bd. 89, H. 1–4.)

calls it—is greatest at the equator. If this tendency be great enough to overcome the cohesion of the bone elements, there must occur a break, a crack, which necessarily will run in the direction of a longitudinal meridian—in fact, between any two of them by whose separation the crack has been formed; and the crack will therefore cross the equator at right angles, that is, in the same direction as that of the compressing force; in the present instance in the direction from side to side over the vertex and round through the base. Moreover, the break will *begin* at the point of greatest distention of the meridian, which is at the equator, midway between the two poles. Such are the bursting fractures of Messerer and von Wahl, and the Messerer-von-Wahl law is thus expressed: "The fracture by bursting due to bilateral compression always runs in a direction parallel to that of the compression." The accompanying figure (Fig. 15), taken from an article by Ali Krogius (*Deut. Zeit. f. Chir.*, Bd. 89, Heft 1–4), is the best that I have met with to illustrate this mechanism, which, perhaps, is somewhat difficult to understand from words alone. It represents a hollow ellipsoid (A) the shell of which is divided into a number of segments by longitudinal meridians joining the two poles a and b. The second one (B) of the two figures shows the same ellipsoid compressed from the poles a and b. The diameter ab with its meridians has been shortened to a_1b_1, while cd has been correspondingly lengthened. The meridian segments which previously were in contact at their edges are now sprung asunder as the natural consequence of the change in shape, leaving gaps which are widest at the equator and narrowest at the poles. Such a picture is sufficient to show why bursting fractures of the skull always run in the direction of the longitudinal meridians, and must occur first in the region of the equator. Krogius goes on to illustrate this mechanism still more graphically, using a hazelnut to imitate the skull; and I cannot do better than reproduce his figures. (Figs. 16 and 17.)

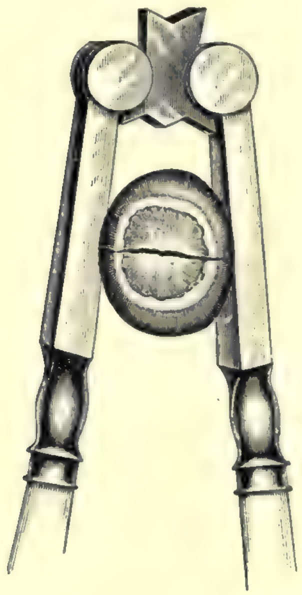


Fig. 16.—Showing the Transverse Line of Fracture when a Nut is Cracked by Lateral Compression.

When the nut was compressed transversely by the nut-cracker, as in Fig. 16, the usual result was a basal fracture, less often a fracture running over the side or through the apex of the nut; in all cases, however, the fissures ran in the transverse direction, following the Messerer-von-Wahl law. If the nut were caught in the longitudinal or diagonal direction, there occurred without fail longitudinal or diagonal fractures of the base. (Fig. 17, a and b.) If it were compressed vertically, there arose one or two fractures which ran from the apex along any one of the meridians, passing through the base. (Fig. 17, c.)

The principle thus enunciated has since been abundantly confirmed. Yet the exceptions, or apparent exceptions, are many. von Bruns said, "If the skull were in all points equally thick and equally elastic, and were its shape an exact sphere, one could calculate the paths of fissures with mathematical accuracy." Unfortunately the skull is not an exact sphere. If a skull be examined against the light, it is evident that its thickness is very unequal, and its shape in the basal portion very irregular. Hold it to the light, and it is seen to be translucent over the orbital plates, the cerebellar fossæ, and in the temporal regions. The base is traversed by numerous openings, the largest of which is the foramen magnum. It is built up of numerous separate bones united by sutures. It has long been observed that certain areas uniting the vault with the base were distinguished by a greater thickness and strength, and these have been called the buttresses of the skull. One runs up in the midfrontal region, another from the external angular process of the orbit, another from the mastoid region, and another in the midoccipital line. The angle which the base forms with the vault varies greatly in different parts of the skull. Thus the orbital plates of the anterior fossa run approximately at a right angle to the vault; the sella turcica and basilar process—or, speaking generally, the middle fossa—dip down at an obtuse angle; while the posterior fossa, with its convexity downward, comes nearest to continuing and completing the spheroidal shape of the vault. All these peculiarities necessarily have a very modifying action upon

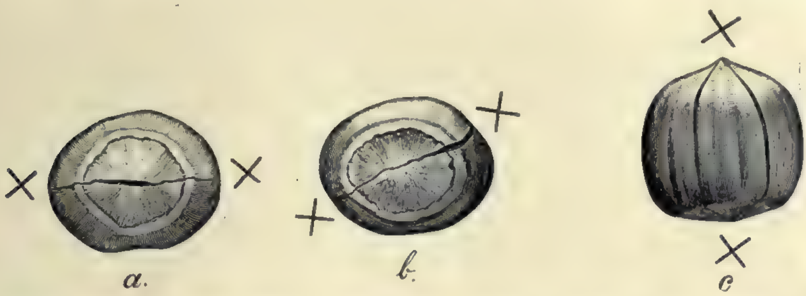


FIG. 17. Showing the Line of Fracture when Compression is made in the Longitudinal Axis (a), diagonally (b), or in the vertical axis (c); a line drawn between the crosses, in each of the figures, indicates the direction of the compressing force.

the physical forces that lead to bursting or bending fractures. The base is plainly the weakest portion of the cranial spheroid, and bursting force may succeed in breaking it, yet fall short of breaking the vault. There are further distinct differences between the effect of bilateral and that of unilateral violence. It has been demonstrated experimentally that it needs from four to eight times greater force to fracture a skull that is swinging free than one which is supported on the side opposite the application of the violence. Moreover, the fracture that occurs will, in the case of unilateral violence, rarely extend beyond the middle of the base, whereas that from bilateral compression may easily traverse the base completely.

Occasionally, as one would expect, there occur two or more bursting fractures from a simultaneous separation along the lines of two or more longitudinal meridians; and these sometimes are quite a distance apart, though running in the same general direction as that of the violence. An example of this is seen in the illustration of the skull of a negro broken by butting, given by Roswell Park in Dennis's "System of Surgery."

Further particulars with regard to the variations from type of bursting fractures will be discussed when we come to speak of fracture of the base.

It is evident that the bursting effect can cause only fissures or diastasis of sutures, that is, linear fractures; and clinically the fact has long been remarked that many of these fractures are confined to the base or go only a short way around the vault. A good illustration of the bursting fracture is seen in Fig. 18.

Impression or Bending Fractures.—As already said, the more localized the violence the more localized will be the effect. And although any violence whatever to the skull has a certain effect on the shape of the spheroid and therefore a slight tendency to cause bursting, still this alteration in shape may be so slight as to be negligible; a great violence acting upon a very small area will overcome the bone cohesion at that spot at the very moment of its application and exhaust its energy in the production of a fracture there; its trans-

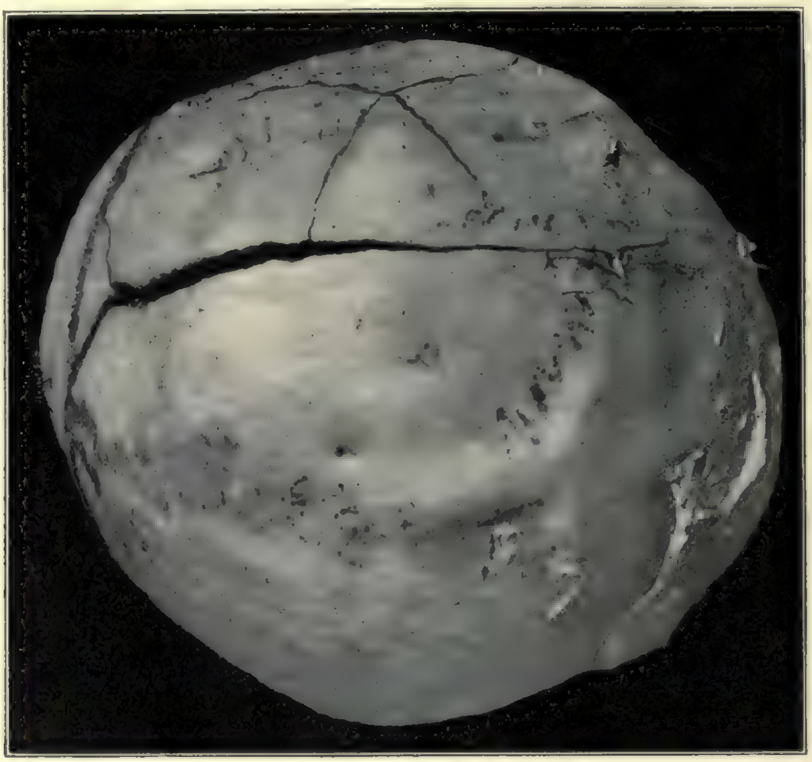


FIG. 18.—Bursting Fracture of the Vault from Bilateral Compression. Note the one long linear fracture widest at the equator and narrowing toward the poles; and the radiating secondary lines at right angles representing Treub's lines of " Krummbiegung," or outbending force. (From the Pathological Museum, McGill University, No. 73, 23, 19).

mission to bone at a distance is minimal. If the violence continue, it will expend itself upon the brain alone. Thus it is necessary to distinguish between the effects of comparatively broad and blunt instruments and those of a pointed instrument. The effect—apart from variations of elasticity in individual skulls as well as in different parts of the one skull—must always depend upon the degree of the violence. In this sense, we can easily distinguish several grades of effect: (1) The convex surface is pressed flat or bent in slightly by the violence, and, the elasticity of the bones not being overstepped, the area of impression immediately springs back to its original shape. (2) A slightly greater degree of violence goes beyond the elasticity of the bone and suffices to cause a fracture. This will occur, however, first in the internal table, not in the external. This fact was long thought by the ancient authors to indicate a greater fragility of the former, whence its name of the "glass table" (vitrea). The fact also that where the whole thickness of the skull was broken the internal table was always considerably more splintered than the external lent support to this idea. It was not until a little over fifty years ago that Teevan demonstrated the error of this conception, and showed that the fact mentioned was merely due to the usual direction of the violence. The classical illustration, hackneyed though it be, of breaking a stick over one's knee is still the best. It is found that the break in such a case begins always on the convex side, that of distention, and not on the concave or compressed side, because the resistance of the wood particles is less to a tearing violence than to one of compression. Likewise with the skull.

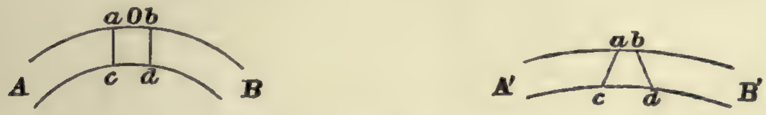


Fig. 19.—Teevan's Illustration to Show the Effect, on the Convexity of the Skull, of a Narrowly Localized Inbending Force.

The accompanying illustration from Teevan will illustrate this fact. (Fig. 19.) It represents the convex outline of part of the skull. At *O* is represented the application of the violence. The result is a flattening of the convexity seen in the second figure, by which the two parallel lines *ac* and *bd*, representing the area of the object causing the violence, are separated, so that *ab* is shortened and *cd* lengthened. The consequence is that the external table is compressed, its particles condensed; while the internal table is distended and its particles pulled apart. Just as in the illustration of breaking a stick over one's knee, in which the break begins at the convex side, so here the internal table is first broken. Thus it is that in every inbending fracture of the skull the internal table is broken more than the external. (Figs. 20 and 21.) Teevan proved this fact still more strikingly by reversing the process of fracture, applying the violence first to the internal table of the skull; whereupon the reverse of the above-described process took place, and the external table was the first to be broken. Clinical confirmation of this fact he found in a specimen from Guy's Hospital Museum, in the skull of a suicide who had shot himself in the right temple. Here the bullet had penetrated to the opposite frontal bone, against which it had struck and come to rest. At this point the internal table was intact, while the external showed a small fracture. von Bergmann adds an equally instructive illustration which he owed to Thiersch. A suicide had shot himself through the mouth. The bullet penetrated the hard palate and the sphenoid, struck against the posterior portion of the inner surface of the left parietal, where it bruised the dura, and then came to rest. The internal table was quite intact, the external fissured. (3) If the violence be somewhat greater, both tables are broken and the fractured area may or may not be depressed.

Here it must be remembered that this inbending effect causes necessarily pressure upon the bone surrounding the area of direct compression. It is a matter of clinical experience that a fracture of both tables with even a very little

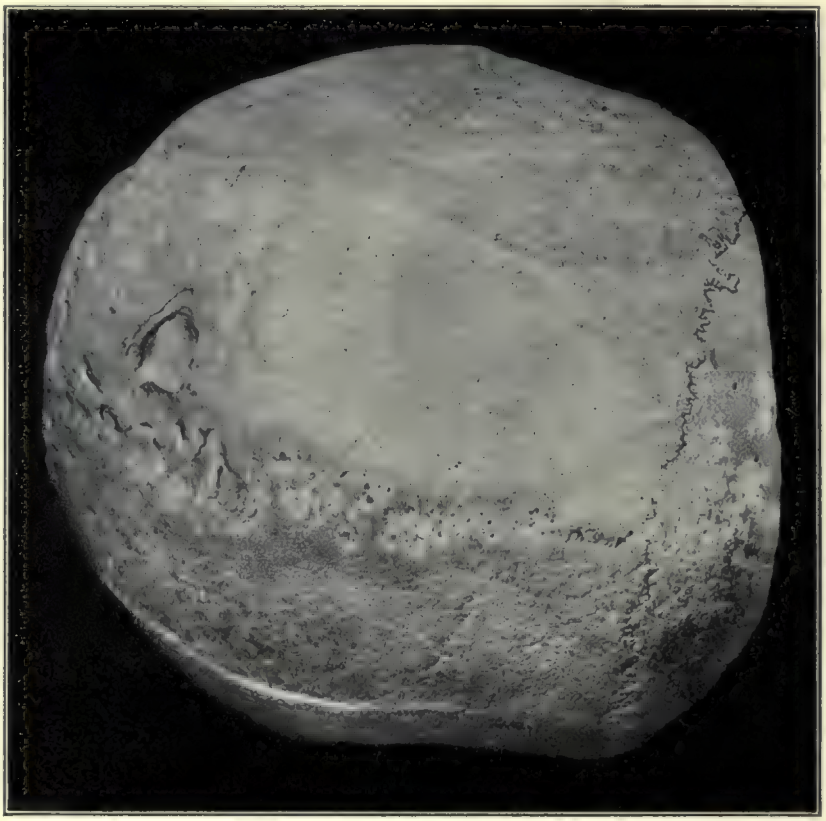


FIG. 20.—Small Depressed Fracture of Vertex. Note the tendency to fissuring in a circumferential direction (the "ring" fracture) just outside the area of depression. Compare with more extensive splintering of inner table in Fig. 21. (From the McGill Pathological Museum, No. 91, 84, 2.)

depression will make such a claim upon the cohesive power of the surrounding bone as to go beyond the limit of its elasticity and to fracture it. Thus in all fractures with depression one finds fissures in the neighboring bone. (See Fig. 22.) One natural exception may be mentioned. The soft cranium of the fœtus or the infant possesses a much greater degree of elasticity and ductility than that of an adult, and there are on record numerous cases of depression of skull bones in the newborn of very considerable extent, without fracture.

A further distinction in the matter of bending fractures was made by Treub, who established two types of bending—inbending (Flachbiegung) and outbending (Krummbiegung). The former designated the local circumscribed effect, apt to result in a depression of the area struck; the latter represented the effect upon the bone at the periphery of such a depressed area. Here the condensation of bone produced by the inbending naturally causes a forcing outward at the periphery against the inert remainder of the vault; in which action the mutual opposition is toward the surface because of the tilting upward of the plate of bone at its edge, all around the depressed centre. This fact has been graphically demonstrated, though otherwise interpreted, by Chipault and Braquehaye,* who, upon the application of localized violence, observed, and

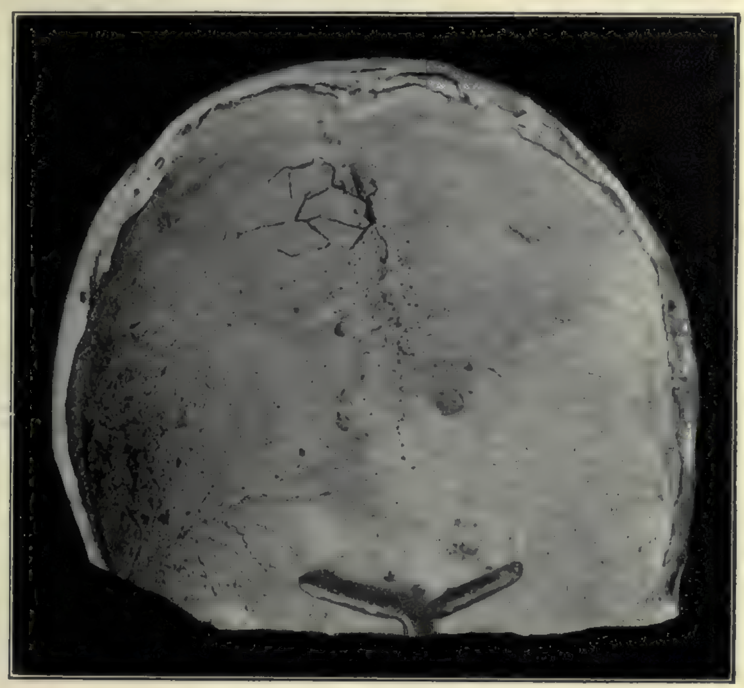


Fig. 21.—Splintered Fracture of Inner Table, without Depression, Corresponding to Small Localized Depression of the Outer Table seen in Fig. 20. Note the more extensive character of the break. (From the McGill Pathological Museum, No. 91, 84, 2.)

recorded on smoked paper by an ingenious contrivance, an area of inbending (zône de dépression) corresponding to the area struck, and an area of outbending (zône de soulèvement) corresponding to all the rest of the skull. The junction of the two zones lies, of course, at or near the periphery of the depressed area, and represents the line of outbending force; and following this line there will usually be found clinically a fissure surrounding a depressed fracture, to which is given the name of "ring" fracture. If the instrument employed were angular in shape, the ring fissure also becomes more or less angular. On the other

* "Études graphiques sur les fractures indirectes de la base du crâne." Travaux de Neurol. Chir., 1895, tome i., p. 30.

hand, where the violence has acted in the sense of bilateral compression, and there occurs, not a depressed fracture, but a bursting one, there will occasionally be found a fissure running at right angles to the bursting fracture (see Fig. 18); such a one represents the outbending effect; only here, in contrast with the localized "ring" fracture, surrounding the area struck, it appears further removed, near or in the equator. In the accompanying figure (Fig. 23) representing a sphere compressed between a and b, the outbending (Krumm-

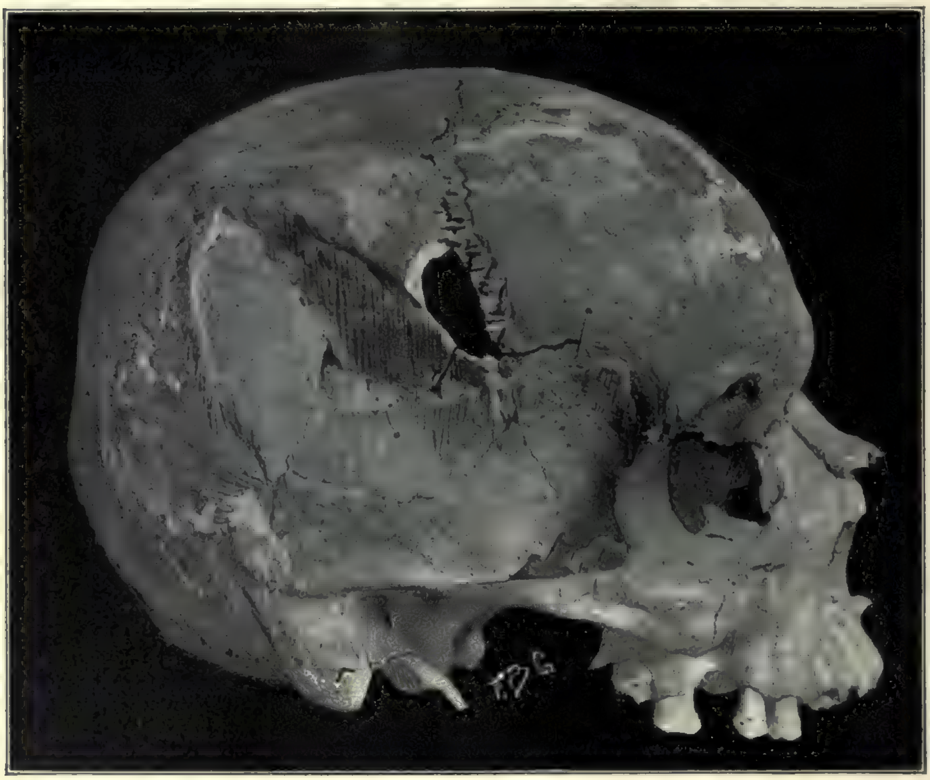


FIG. 22.—Depressed Fracture of Right Parietal Bone. The border of the large area of depression is indicated by the shading. Note radiation of the lines of fracture outward from the central depression. These represent probably the wedge effect of a gunshot wound. (From the McGill Pathological Museum, 91, 84, 3. Specimen dates from the War of 1812.)

biegung) fissure will run in the direction cd, while a bursting fracture would run between a and b. All the bending fractures, therefore, run approximately in the line of the parallels of latitude—near the pole of violence if the latter be circumscribed and unilateral, and near the equator if the violence be diffused and bilateral; whereas all the bursting fractures run approximately in the line of the meridians of longitude, tending to unite two opposite poles of compression, and beginning at or near the equator, which they traverse at right angles.

Between these two types of bursting and bending fractures lies a wide class of combined fractures. In such instances it is frequently difficult to see where one begins and the other ends. In many injuries the very nature of the violence is in itself a combination of the two main types, combining the principle of bilateral compression with that of the blow. Thus the blow of a hammer on the head while the victim is lying in bed must produce both the bursting and the inbending effect. Whether the one or the other will predominate must depend upon the extent of the skull area struck, the sharpness or bluntness of the instrument, the chance elasticity of the victim's skull, the particular part of the skull struck, the degree of the violence, and the presence or absence of counter-support, which determines the degree of bilateral compression.

The man whose head is compressed "between the ends of logs protruding from neighboring cars" will probably suffer a pure bursting fracture. He who, while lying in bed, is struck with a hammer will probably show a pure inbending

FIG. 23.—Diagrams to Illustrate the Direction of Outbending and Bursting Fractures of the Skull.

fracture with or without depression. On the other hand, when the head is not supported, save by its attachments to the trunk, there will be a combination of bursting and inbending, the one predominating over the other according to whether the area of impact be diffuse or circumscribed, and according to whether the instrument be blunt or pointed.

There is one very large class of fissured fractures the exact mode of whose causation is somewhat undecided. They represent those cases in which a fissure of the vault is found spreading for a variable distance from the area of impact of the violence, often, indeed, as far as the base, and where the violence has been diffusely applied without counter-support to the head. From the fact that they gape widest at the area of impact, it is generally conceded that the fracture began at this area. In that particular, they differ from the typical bursting fracture from bilateral compression, which begins at the equator. Are these to be explained as bursting fractures or not? Bohl's experiments* furnished a fairly sufficient answer to this question. He found by accurate measurement that the diameters of the skull underwent, under unilateral violence by blow without counter-support, the same alterations, though to a less degree, of shortening in the direction of violence and lengthening in the other directions, as they did under slow bilateral compression. In other words, the elasticity of the skull, and consequently the bursting principle, came into play

* Bohl: "In Sachen der Schädelbrüche." Deut. Zeit. f. Chir., 1896, Bd. xliii., p. 537.

under the one as under the other condition. The fractures produced by a blow upon the suspended skull were found to begin at or near the point of impact. As I take it, this simply means that the counter-support is still present; only instead of being applied extrinsically to the opposite pole of the skull, it resides intrinsically in the skull's own inertia and in the natural cohesion of the bone particles, that is, in the convex plate of bone extending from the immediate neighborhood of the area struck as far as the equator in the shape of an arc. Bohl has further called attention to indirect isolated fractures of the base due to bending, and not to bursting. The most important of these is a transverse fissure through the sella turcica upon fronto-occipital compression. The angle which the sphenoidal body makes with the clivus affords, as he points out, a weak spot, which, upon compression, is apt to give way; it simply doubles up. A similar transverse fissure is less often seen on either side of the foramen magnum upon fronto-occipital compression. These fractures occurred with considerable frequency in his experiments; but were always subsidiary to true bursting fractures running longitudinally through the base.

The third mode of action of violence has been already referred to. It is the wedge effect typically seen when a chisel is driven into the skull. This is not the same as the bursting effect; the fissure separates at the point of application of the wedge, not at a distance as in bursting fractures, and spreads laterally. To my mind, it affords the type of the irradiation fracture of Aran, which will be referred to later. Clinically it is seen in injuries from flying splinters of wood or metal, including certain of the effects of bullet wounds; and also in hatchet or axe wounds.

The nature of the explosive effect will be discussed farther on in the section on Gunshot Wounds.

Pathological Anatomy.—With this knowledge of the mechanism of skull fractures as a basis, we are prepared to understand the ordinary classification of the various forms of fracture. The main types have already been partly indicated.

(1) *Fissures or Linear Fractures.*—Here the cleft is not usually wide; it is often a mere crack, and in its basal portion may be discovered only after maceration. Its course may be very short, or may be so long as completely to encircle the skull, dividing it practically into two halves. Its direction over the vertex is frequently straight, but over the base is usually very irregular, with many small deviations, although it still ordinarily pursues a fairly direct general course.

The fissured fracture is also very frequently found radiating for a variable distance outside of an impression fracture with or without depression. Where the instrument has been a blunt one and the fissure is found to be single or double, it may be accepted as an example of the bursting fracture. But where, as in many cases, especially those fractures with loss of substance, such as are produced by pointed instruments or bullet wounds, the fissure radiates in all directions from the centre of the fracture, the effect is certainly a wedge one.

(2) *Splintered or Comminuted Fractures.*—These represent the type of the inbending fracture. The break is usually confined to a small area and is circular, angular, or quite irregular in outline. The fragments may be single (a condition called by the Germans "Stückbruch") or multiple. Much oftener the latter is the case, and the fracture is comminuted. Their number is frequently quite large; Roswell Park says that they occasionally exceed twenty-five. Their shape is of the most various: flat buttons, angular or round, pointed pieces varying from a triangle to the splinter or needle shape, and sometimes very minute fragments. In depressed fractures the position of the fragments varies greatly. The fragment may be single, and there may be no penetration and very slight contusion of the dura; at the other extreme the fragments may be very numerous, and be driven far into the brain; or one splinter may be turned at right angles and its point pushed through the dura and into the brain, like a stalactite. Occasionally the extent of the fracture is very great and the whole side of the skull may be crushed. Depressed fractures are classified into central and peripheral. In the former the depression is at the centre, while the periphery remains partially attached to the surrounding bone. In the latter there is no attachment at the periphery, the whole fragment is broken loose.

As already said, there is frequently a circular or angular fissure which runs a little outside the main area of fracture. In falls upon the vertex, for instance, where the full weight of the body impinges upon the occipital condyles, the occipital ring surrounding the foramen magnum may be crushed in, with the production of a "ring" fracture. Further, crossing this circular one after the fashion of a spider's web, there are often seen, radiating from the depression, fissures which thus cause partial separation of a number of fragments outside the chief zone of fracture. This is especially seen in bullet wounds, and represents a combination of the inbending with the wedge action.

(3) *Fractures with Absolute Loss of Substance.*—This variety is usually caused by the penetration of bullets or of blunt-pointed instruments. If the hole is small, they are called punctured fractures. They are particularly apt to be associated with the radiating fissures due to the wedge or bursting action. They will be discussed in more detail in the section upon gunshot wounds.

The effect on the tables of the skull is usually, as already said, that the internal is more broken than the external, and this fact is of great clinical importance. At operation, if one find a small external break, one may count upon it that the internal table has suffered a much greater fracture, with possible wounding of the brain substance. Occasionally the external table alone is broken; but in such a case the fracture must be extremely small, save in the mastoid and frontal regions, where the two tables are separated by large air spaces. On the other hand, the internal table is, in rare instances, the only one broken. The mechanism of this has already been discussed.

We have gone into the Messerer-von-Wahl-theory in some detail because we believe it to be the most rational conception of the mechanism of cranial fractures; yet it was, at least as regards fractures of the base, preceded by two other theories which long enjoyed general acceptance. The first of these was the "contre-coup" hypothesis, by which the violence was supposed to be transmitted in waves of vibration from the area of impact in the vault around to the base; at which point the clash of their meeting resulted in fracture. This theory, emitted chiefly by Saucerotte in 1768, and supported by Chopart and Sabouraut in 1778, held sway for nearly a century. It was not till the middle of the last century that Aran in France disputed the conception, and established the theory of fracture by irradiation. This simply meant that the violence acted most intensely at the point struck, causing here a fissure or a comminuted fracture; and that the rest of the force not thus exhausted was expressed in a splitting action which was irradiated from the central zone of injury. He maintained that this fracture by irradiation, which was always a fissure, took its course through the vault and to the base along the shortest possible line; and that there did not exist fractures of the base which were not a direct continuation of a fracture of the vault, beginning at the area struck. Félizet shortly afterward modified this theory by pointing out that the fracture frequently did not take the shortest line to the base, but a line which was modified by the local structure of the skull in the neighborhood of the violence. He showed that the fissure tended to run through the weaker portions of the base, and to avoid entirely the natural buttresses of thick bone substance, of which mention has already been made. With this modification the theory has been widely accepted. To the writer, it seems to do no more than state the fact of fracture; it does not explain its mode of causation.

Lately, Rawling* has proposed several modifications of this irradiation theory, and has brought forward one or two new points concerning the mechanism of skull fractures. He declares himself unable to accept either the contrecoup or von Wahl's bursting and compression theory: the latter on the one hand because he sees very slight evidence of bilateral compression in the usual clinical occurrence, and on the other because he believes the elastic properties of the skull to have been greatly exaggerated. His own opinion is that Aran's irradiation theory, with certain modifications, accounts satisfactorily for those basic fractures which result from blows on the vertex,—from thirty to forty per cent of the cases examined by him,—but, and this is the new part of the matter, that most basic fractures—over sixty per cent—result from force applied directly around the basic level, which latter he seems to regard as essentially a plane surface closing in a truncated sphere, the vault. He believes also that these fissures are the result of a splitting force, the line of fracture tending to travel across the base parallel to the original direction, but not necessarily in the same

* L. B. Rawling. "Hunterian Lectures on Fractures of the Skull." Lancet, Apr. 9th, 16th, and 23d, 1904.

straight line. The statement that all basic fractures result as extensions from the vault (Aran) is analogous to putting the cart before the horse, since many of these vault fractures, he believes, result as extensions from the basic region. He points out very emphatically the fact of the great irregularities in the structure of the base already referred to—the buttresses, the foramina, the air sinuses, the hollowing out of the petrous bone for the auditory apparatus, the paper-like thinness of the bone in one part and its thickness in others—and the deadening effect of the sutures on the transmission of violence: and he concludes that the fracture by irradiation of Aran and the fracture by splitting from direct violence take a course which, by careful comparison of the direction of the applied force and the point of application, can be predetermined with a great degree of probability. This course lies roughly in the direction of the application of the violence, but is modified by the peculiarity of basal structure just mentioned; the main point being that it tends to follow the lines of weakest bone structure; for instance, the orbital plates, the petrous bones, the sphenoid and the cerebellar fossæ; and to run between the thicker buttresses uniting base and vault.

As may be seen, the conclusion as to fact with regard to the course of basal fractures corresponds perfectly with that of Messerer, von Wahl, and others. The disagreement lies in the interpretation of the mechanism. Without wishing to discuss theories at any length in a work of this character, it may be said that the criticism of Rawling's view which naturally suggests itself is this: that he makes no distinction between the effect of the diffuse violence and that of the circumscribed one. He seems to assume a wedge or splitting action from the application of a diffuse and blunt violence, and this is difficult of acceptation. As I believe, all fissures from this kind of violence are the result of the bursting principle. On the other hand, he ignores the effect of momentum and of inertia in affording counter-support; and in general he attaches insufficient importance to the effect of bilateral compression.

Walton (*Annals of Surgery*, Vol. XL., 1904) has also contributed to this subject a study of fifty cases of basal fractures. As to the underlying mechanical principles, he adopts an intermediate standpoint.

Diagnosis of the Course of Fissured Fractures.—It has been said that, according to the law of bursting fractures, a break in the bone, if the skull were a perfect sphere of equal elasticity and thickness throughout, must take the direction of the meridian joining the poles of compression. Clinically, however, while the fracture may take a fairly straight course through the vault, the very unequal structure of the base will necessarily cause many deviations from such a mathematically straight line; so that in this matter we must fall back upon an analysis of as many cases as can be collected and carefully studied.

von Bergmann indicates two favorite directions taken by the line of fracture. The one runs parallel to the long axis of the petrous portion, the other lies farther forward in the great wing of the sphenoid; both run transversely. This simply means that the usual direction of the violence is transverse. Such an approximation, however, is naturally insufficient; and numerous investigations have been made in the endeavor to determine with greater exactitude the line of the fracture under varying conditions. Rawling came to the conclusion that certain definite lines of fracture corresponding to definite directions of the application of violence could be established as typical. They recurred so frequently as to enable him to make a diagnosis of the extent and direction of the fracture under any given conditions.* Walton, in examining records of fifty cases, found that in twenty-two of these the lines of fracture were similar to, or suggested, those of Rawling as well as von Wahl's lines of bursting fracture, and that they fell almost invariably between the natural buttresses of the skull, indicated by various anatomists, extending from the vault to the base in the midfrontal, external angular, mastoid, and occipital regions; results which tended, therefore, to support the statement that basal fractures are prone to follow lines of least resistance. His diagrams of the other twenty-eight cases, however, showed results so variable as to make it plain that the exceptions to Rawling's very exact lines, far from being occasional, were in the majority. The writer has also examined carefully the post-mortem records of 50 cases† and has come to results that agree in the main with those of Walton.

When one compares the diagrams of von Wahl, Rawling, and Walton, it is easy to arrive at the conclusion that, no matter what the theory of the mechanism may be, and in spite of the exceptions, the main fracture runs always approximately in the direction in which the violence was applied. It may not extend throughout the whole course indicated in Rawling's lines, yet it will usually run at least in that direction. Thus, when the violence is frontal, one finds usually the fissure running through one orbital plate (rarely both), going on through the body of the sphenoid, most often through the sella turcica, then deviating to one side or the other, proceeding along the petro-occipital suture to the jugular foramen, and so along the masto-occipital suture back to the vault. With the application of the violence over the external angular process of the frontal bone, the fissure takes an oblique course through the orbital plate to the sella turcica, and, if the force be great enough, may go on to the middle fossa on the other side. A fracture from violence applied to the parietal region has a great tendency to cross the skull transversely in the middle fossa, running through the petrous portion, and not infrequently opening the middle ear and the drum membrane, proceeding to the sella turcica, and then, if the violence be considerable, not infrequently back through the petrous portion of the other temporal bone. If the violence be delivered through the mastoid region, that is, obliquely from behind, the fracture takes an oblique direction, entering

* For this exact course the reader is referred to the original, the details being too lengthy to reproduce. In the essential, they confirm, very evidently, the bursting theory.

† A considerable number of these were from the Montreal General Hospital; and I have to thank the authorities of this hospital for their kind permission to use their records.

first the posterior fossa laterally, in most cases, and proceeding occasionally as far forward as the opposite sphenoid or even the orbital plate. A fracture from occipital violence runs more or less in an antero-posterior direction near the middle line through the posterior fossa, going either through or alongside of the foramen magnum, and then deviating slightly to the side, and traversing the long axis of the petrous portion of the temporal bone, occasionally going as far forward as the sphenoid. With a blow upon the mid-vertex the fracture is usually longitudinal, involving mostly the posterior fossa and the posterior portion of the petrous bone. This is plainly a bursting fracture, counter-compression being given by the occipital condyles.

In these basal fractures from blunt violence, therefore, it may be said, to put it briefly, that the approximate course may be predicted with great certainty as being that of the direction of the violence, whereas the exact course of the fissure is absolutely and inevitably uncertain. One other point. Frequently, with injury applied to the vertex, the fracture is found, not at the site of the injury where the bone is thick, but in the base, where it is thin. This one fact, to the writer, seems an extremely strong argument in favor of the bursting principle as opposed to the theory of irradiation. As to the length of the fissure, that can only be approximately gauged from possible accompanying signs, such as bleeding from the orifices, lesion of nerves, or disturbance in the basal parts of the brain.

It is hardly necessary to detail figures relating to the frequency of implication of the various fossæ, as this depends so much upon the direction of the violence. One point, however, worth mentioning is that all fractures, as Rawling points out, tend to converge toward the pituitary region. He found the sphenoidal sinus broken in seventy per cent of his cases.* Fractures in the posterior fossa frequently remain undiagnosed because of their lack of clinical signs.

A special paragraph must be given to fractures of the skull in children. The bone of the new-born and of infants being extremely elastic and pliable, fractures by bursting or by wedge irradiation are naturally infrequent. The bone bends rather than breaks. Numerous instances are recorded of such injuries during birth; indeed, nearly every practitioner has occasion to see this variety in the new-born child at some time or other. In one instance recorded the depression was so extensive that an egg might be laid in the cavity. Inasmuch as there is a great deal of fibrous tissue between the various bones of the skull, there exists a great tendency for the fracture to be limited to the bone struck, and therefore basal fractures are rare. It is important again to remember, especially in regard to injury in the frontal region, that in the child the air sinuses do not exist, or are very small. With growth the bone acquires fragility and

* In my own series, of 32 basal fractures the middle fossa, alone or in combination, was involved 23 times. In 4 cases, the fissure ran through all 3 fossæ; in 10 through the orbital plate and middle fossa; in 3 through the middle and posterior fossæ; in 4 through the posterior alone; in 6 through the middle alone, and in 5 through the orbital plate or plates alone.

loses ductility; and during later childhood fractures gradually approach the type seen in adults. Gasne has lately published an excellent thesis on this subject. (Ernest Gasne: "Les Fractures du Crâne chez l'Enfant." Thèse de Paris, 1905.)

The mechanism of fractures of the skull as explained above hardly required the formal establishment of two classes, those of the base and those of the vault. It is evident that the inbending fractures will concern almost entirely the vault, while the bursting fractures will involve any or all parts of the skull, according to the degree, situation, and character of the violence, at one time causing a basal fracture alone, at another a vault fracture alone, but usually the two together in varying extent.

Symptoms and Diagnosis in Fractures of the Vertex.—There is, I believe, every reason in the discussion of this section to separate fractures of the vault from those of the base, inasmuch as in the one case the diagnosis and symptoms are or may be matters of direct evidence of the senses, whereas in the other they are mainly indirect or inferential.

It is evident that in many of those instances in which the violence has been severe, the diagnosis lies before one's eyes. A compound, comminuted fracture may be told at the first glance or the first touch. Such cases may be left out of the discussion. At the other extreme lie the instances of very slight injury, where, *a priori*, the idea of a fracture is most improbable. Where, however, there has been unconsciousness even of the most transitory character, it would be most unwise to assert positively the absence of fracture.

It is hardly necessary to warn against the error of mistaking for a fresh fracture a pre-existent irregularity in the skull surface, such as might be caused by previous trauma, a syphilitic loss of substance or hyperostosis, or a congenital or senile abnormality. Such things would be ruled out by a careful history and the absence of evidence of trauma in the overlying soft parts.

In simple fractures the difficulty in making the diagnosis is much greater than in those which are compound. In the latter, if the break lie open in the depths of the wound, the mere fact of fracture is settled, yet the finer diagnosis may be difficult. Thus a minute fissure may be confounded with a suture line or the depression lodging an arteriole. A proper anatomical knowledge of the direction of the sutures on the one hand, and on the other the welling up of blood through the fissure after sponging, will prevent a mistake in either direction. According to von Bergmann, Hippocrates once mistook the sagittal suture for a fracture; and it is still worth while reproducing the anecdote of Saucerotte (found in all the older books), who rescued a poor priest from the imminent danger of the trepan by showing that the supposed fissure was no more than the suture line of an occipital Wormian bone. It is pleasant to relate that, in the sequel, the grateful man willed his skull to his rescuer.

In the second place, it may be difficult in a given case to determine whether the outer table alone is broken, or the whole thickness of the skull. Fissures practically always extend through both tables. With inbending fractures one must take it as a rule that the internal table is more extensively broken than the external, and this is the one essentially important fact of the whole matter. Only when the depression is very small, especially if it be situated over an area in which the diploë is abundant, or over the frontal or mastoid sinuses, may one suspect that the external table alone is broken. Such measures as probing, with the view of making a more exact anatomical diagnosis, are to be condemned; they are unnecessary and may be harmful. *Nil nocere!* If fracture be suspected, but not easily visible or palpable in an open wound, it is better to leave the diagnosis uncertain and treat the wound according to ordinary principles, unless, of course, concomitant symptoms of brain injury make it important to determine the nature of bone injury in view of possible operation.

With simple fractures the diagnosis is much less easy. Signs of cerebral lesion have no value for or against the presence of fracture, inasmuch as frequently the brain is contused in the absence of material skull lesion. One is reduced to the evidence of palpation. Even so, the linear fractures without depression must remain impossible of diagnosis by this method. They may certainly be suspected strongly if, the patient being conscious, there exist ecchymosis or a line of tenderness to pressure, and this be unexplainable by the presence of contusion of the soft parts. On the other hand, palpation may detect a depressed fracture by discovering its raised edge, or a possible splinter out-turned. Nevertheless, this sign too will often be lacking because of the swelling of the scalp in the neighborhood from hemorrhage and reactionary effusion. Moreover, the timeworn warning must not be forgotten as to the marvellous simulation of the bony edge of a depression by the indurated periphery of a hæmatoma. This is a mistake which is very easy to make, which every house-surgeon entering upon an accident service is fore-resolved not to make —and does make. On the other hand, it must not be forgotten that underneath such a hæmatoma there may still be present the depressed fracture.

After all, in these unclear cases it is well to hark back to principles. I mean those of the mechanism of skull fractures. Thus it is unlikely in the case of the vertex, which is the especial seat of inbending fractures, that any considerable blow from an instrument of narrowly localized impact-surface will leave the skull quite unbroken. If the instrument be broad and blunt the bursting principle comes more into the sphere of calculation, and consequently a fissure of the vertex is the less likely, while one of the weaker base gains in probability. If there has been bilateral compression of any severity a bursting linear fracture is the almost inevitable result, but it may involve the vertex little or not at all, the base usually suffering the most.

A good skiagram, in places where such is available, is naturally the ultimate test. I speak here of vault fractures, not of basal, which will always remain difficult and often impossible of photographic proof. The fissures of bursting fractures of the vault can be traced for a variable distance in skiagrams where the frontal, temporal, or parietal bones are involved.

The signs of lesion of the intracranial contents, so necessary for the diagnosis of fracture of the base, are here of secondary importance. Loss of cerebro-spinal fluid is rarely seen in fracture of the vault.

One peculiar sequence of the simple cranial fracture, seen almost exclusively in young children, is the persistence of the fissure and the subsequent gradual separation of its edges. The gap is occasionally closed by fibrous tissue; yet often enough there protrudes through it a meningocele. Gasne,* who has discussed the subject very thoroughly, believes that the persistence and widening of the fissures are due to rickets, aided by the rapid development of the brain in early years and the consequent increase in intracranial tension.

Symptoms and Diagnosis in Fractures of the Base.—Here the symptoms upon which a diagnosis is established are of quite a different nature from those concerning the vault. The fracture being inaccessible to sight and touch, we must rely upon circumstantial proof. Fortunately, this is sufficient in very many instances to give us a more or less exact idea not only of the fact of a fracture, but also of its location and extent.

Speaking broadly, the diagnosis must be based upon a consideration of: (*a*) The nature and direction of the violence; (*b*) signs dependent upon the hemorrhage from broken bone; (*c*) signs dependent upon the escape externally of intracranial contents; and (*d*) symptoms due to lesion of the basal cranial nerves.

a. As to the first, we have already sufficiently indicated the relation existing between the nature of the violence and the occurrence of basal fracture. Save in the punctured wounds of the base and in the radiating fissures due to bullet wounds or the action of instruments that split the bone, as does a wedge, the break, as I believe, is always due to the bursting effect. The value of this observation is chiefly as a confirmatory sign where other symptoms or signs are insufficient. For instance, if some little while after a blow from a sand-bag upon the occipital region there appear a subconjunctival or palpebral ecchymosis, in the absence of any direct injury to the frontal region, we are justified in assuming the great probability of a bursting fracture, which has extended from the posterior to the anterior fossa, with break of the orbital roof. On the other hand, if the injury to the occipital region has been inflicted by a more or less pointed instrument, with the production of an inbending fracture, one would assume that any coincident orbital hemorrhage was due to a lesion of the proper orbital vessels from concussion or a possible fall upon the forehead rather than to a fracture of the orbital plate.

b. The blood effused from a fracture of the base will appear at the surface in one of various situations corresponding with the site of fracture: in the orbit,

* "Les Fractures du Crâne chez l'Enfant." Thèse de Paris, 1905.

eyeball, or eyelids, in the pharyngeal mucosa, in the mastoid region, or in the side of the neck. It would be erroneous, however, to imagine that the ecchymosis of these regions, following a cranial trauma, always indicates fracture of the base. A local injury to the external area in question must first be excluded and, second, the ecchymosis must be of late appearance, that is, hours or even days after the injury, varying with the distance of the fracture from the surface. These are general qualifications; there are others which concern the particular region involved.

Hemorrhage in the Neighborhood of the Orbit.—The blood in these cases may appear in one or all of three main situations: in the lids, in the subconjunctival tissue, and in the retro-ocular orbital fat. In the latter case its clinical expression lies in an exophthalmos. The orbit is commonly fractured in one of two ways: by a bursting fracture through violence at a distance, or by direct violence, usually from a blow on the temple (external wall) or from the thrust of a stick or other similar instrument from in front (the roof). It is important, moreover, to know that the bleeding from a fracture of the orbital roof extends nearly always into the orbital fat as well as toward the intracranial side. It is almost superfluous to state that an ecchymosis into the lids, the ordinary black eye, is more often due to a local lesion than to an orbital fracture. The blood from an injury of the forehead may easily extend by gravity into the lids. If, however, the violence be indirect and the ecchymosis be confined to the tissues anterior to the tarsal and ligamentous structures of the lids, not appearing on the conjunctival surface, one may suspect a fracture limited to the perpendicular plate of the frontal bone.

The subconjunctival hemorrhage, too, is very frequently due to contusion of the eyeball from a blow. In von Bergmann's opinion, even comparatively slight concussion of the orbital contents, the transmitted violence of a distant trauma, may rupture the delicate vessels of the conjunctiva; and he instances the well-known extravasations in the sclerotics of children with whooping-cough. Therefore the ecchymoses in these situations have no value as indicating a basal fracture unless their appearance be delayed for a number of hours or days. Rawling says that subconjunctival hemorrhage, when due to orbital fracture, nearly always makes its appearance at the outer canthus of the eye, progressing inward toward the corneo-scleral margin. On the other hand, palpebral hemorrhage usually begins at the inner angle of the eye, progressing outward into the tissues of the upper and lower lids. The tarso-orbital fascia extending from the orbital border to the tarsal edge opposes a certain barrier to the exit of blood from the orbital fat into the subcutaneous tissue of the lids, so that, as von Bergmann points out, the subconjunctival ecchymosis usually appears before the palpebral.

Exophthalmos.—Exophthalmos points naturally to a considerable blood effusion behind the bulbus oculi. The small arteries of this region are unlikely to give rise to any hemorrhage sufficient to cause more than a slight proptosis; but there are two larger vessels whose rupture may easily do so. These are the orbital branch of the middle meningeal artery running in at the outer angle of the sphenoidal fissure, and the cavernous sinus. Rawling has, very usefully, tabulated the cases of proptosis into three main groups, a classification which is worth reproducing:

1. Proptosis, severe, appearing almost at once, and progressive. Here a severe fracture in the region of the sphenoidal fissure and cavernous sinus is probable, with copious extravasation of blood forward. Thrombosis of the latter may coexist, and in the most severe and progressive cases there may be some damage to the internal carotid artery. 2. Proptosis, moderate, and appearing after a few hours. This will indicate a fracture involving the orbital walls, the extravasated blood being derived from lacerated ophthalmic vessels. 3. Proptosis appearing days or weeks after the injury, and usually steadily progressive. Here one can diagnose a fracture involving the region of the cavernous sinus with injury to the carotid artery and the formation of an arteriovenous aneurism.

Ecchymosis in the Mucosa of the Naso-pharynx.—Ecchymosis in this region is naturally rarely seen, or at any rate rarely looked for. Fracture of the basilar portion of the occipital would be the most likely cause, and this is rather infrequent. Possibly, however, if looked for, it might be found to be frequent enough in conjunction with the hemorrhage into the nose from ethmoidal and sphenoidal fractures.

Nosebleed.—Actual hemorrhage into the nose and the naso-pharynx, on the other hand, is of very frequent occurrence. The majority of basal fractures involve either the anterior or the middle fossa, and in the great majority of these the cribriform plate of the ethmoid, or the sphenoidal body, is broken, with resulting opening of the naso-pharynx. Thus we find mention, in most case reports, of the vomiting of blood, or its escape from the nose. Rawling lays emphasis upon the severe nature of the break in the sphenoid: "These fractures (he says) are generally comminuted, both roof and floor of the sinus being equally damaged in such a manner that a probe may be passed from the cranial cavity into the naso-pharynx below." His point of view, however, is perhaps biassed by the consideration of post-mortem specimens alone. Clinically there is little doubt but that the sphenoid is frequently the site of a fissure of slight severity, sufficient to cause some bleeding into the naso-pharynx, yet not comminuted, and not injuring the adjacent cavernous and circular sinuses. That, nevertheless, the probability of immediate death is ever present in cases of sphenoidal fracture is seen in Rawling's report of two cases of tear of the internal carotid by a spicule of the comminuted sinus wall. Here "blood gushed from the mouth in streams, and death resulted almost immediately." Crandon and Wilson, in 530 cases of basal fracture, found 44 with pharyngeal hemorrhage, of which number sixty-one per cent were fatal, a high mortality. In the oft-quoted figures of Sir Prescott Hewitt, we find that bleeding occurred from nose or mouth in 14 out of 32 cases of fracture of the middle fossa, all verified by post-mortem examination.

Naturally, as with the orbit, a purely local lesion of the naso-pharyngeal mucosa, or of the nasal bones, may cause hemorrhage in the absence of basal fracture.

In many cases absolute diagnosis will be impossible. Undoubtedly, in hospitals the help of the specialist is not sufficiently sought in these instances of cranial fracture. With his assistance the future may yield us statistics of greater value than those we now possess. Under ordinary circumstances the physician must go upon general principles. Any large or persistent hemorrhage is due with great probability to a fracture of the base, with wounding of one of the larger vessels. Intracranial bleeding causes intracranial tension, and blood is actually driven out of the skull through the fortuitous opening of the fracture. Purely local bleeding in the nose will very shortly cease, unless a vessel of some size be injured. Yet how relative such considerations must be is evident. The ordinary nosebleed is frequently difficult to arrest. It should be remembered that blood in the nose may come from a break in the petrous bone by way of the Eustachian tube, especially when the ear-drum remains intact.

Bleeding from the Ear.—Ecchymosis in the mastoid region frequently coincides with bleeding from the ear. It may come from a fracture of the squamous portion as well as of the mastoid itself. For ages it has been regarded as one of the surest signs of middle-fossa fracture. The line of fracture in these cases, and indeed in most of those involving the middle fossa, runs through the roof, occasionally also the floor, of the external auditory meatus, through the anterior and internal angle of the middle ear, usually tearing the drum membrane, and often dislocating the malleus and incus, and then on through the petrous portion toward the sphenoid body. The blood may come from one or both of two sources: from some part of the ear external to the middle ear, or from a fracture of the petrous portion of the temporal bone running through the middle ear, possibly also through the external canal, and tearing the drum membrane. In order to assure the diagnosis of the latter we must exclude bleeding arising in an isolated tear of the drum membrane in an independent fracture of the bony wall of the external auditory meatus, or in a tear of the soft parts lining it. Such a differential diagnosis may be easy enough in the simple cases, such as those of slight or moderate direct violence upon the external ear, as from a blow; but in the majority of instances it will be impossible to say that no basal fracture is present. Indeed, I believe with Rawling that the text-books have laid too great stress upon the idea that bleeding from the ear may result from local lesion without basal fracture. Certainly, when the hemorrhage is of any material amount, and the violence indirect, fracture of the base is to be assumed.

The drum membrane is not necessarily torn in all cases, for a fissure may extend into the roof of the external auditory meatus, leaving the membrane intact; and if the skin of the meatus be torn, the blood will thus find its way directly to the surface. On the other hand, bleeding from a fracture will not infrequently remain confined inside the drum when the tympanic membrane has escaped tearing.

If bleeding be very profuse, the likelihood is that one of the large sinuses or the middle meningeal artery has been wounded. It must be remembered that the lateral sinus lies very close to the posterior wall of the drum and the internal jugular to its floor, while over its roof runs a branch of the middle meningeal. Rawling, in his valuable lectures already quoted, regards "profuse and continuous hemorrhage from the ear as very suggestive of an accompanying extradural hemorrhage from the middle meningeal, so much so as to justify operation even in the absence of typical symptoms, if the general condition be grave." By post-mortem examination he found that the fissures running across the tegmen tympani are usually of such a nature that blood can be forced through them into the middle ear, and also that hemorrhage from the middle meningeal was very much more common than is generally supposed to be the case, the slighter forms yielding no clinical symptoms. Walton disputes these conclusions. In his analysis of 50 cases of basal fracture there were 4 of profuse bleeding from the ear, in none of which was meningeal hemorrhage found at autopsy. Conversely, middle meningeal hemorrhage was found in 9 cases, in 8 without bleeding from the ear, in 1 with slight bleeding. The writer's findings support Walton's view.

As to the frequency with which bleeding occurs from the ear in fractures of the middle fossa, we have first the figures of Sir Prescott Hewitt: in 32 instances, 15 times. Of the remaining 17, in 12 the fissure did not involve the middle ear, while in the 5 others it did do so, but spared the tympanic membrane. Crandon and Wilson* found hemorrhage from the ear in 281 out of 530 cases of basal fracture clinically diagnosed; from both ears in 47. Figures like these, uncorrelated as they are with anatomical data upon the line of fracture, possess but small value, save as showing the large percentage in which ear-bleeding does occur. Of course, such figures as Hewitt's have only the value of post-mortem evidence in general, and apply, taking it by and large, only to the severest cases. What the true conditions are in the recovery cases must remain to some extent a matter of speculation. I believe that a great many instances of middle-fossa fracture are unaccompanied by bleeding from the ear and in the past have gone under the rubric of concussion. And we are already finding that the modern routine of careful blood-pressure records and careful neurological examination, so greatly lacking in the past, together with good skiagrams, is constantly revealing the presence of otherwise unsuspected fractures.

* Annals of Surgery, Dec., 1906, p. 283.

The fractures of the posterior fossa remain usually unbetrayed by any appearance of blood on the surface. Occasionally a break of the mastoid may bleed into the middle ear or the external auditory meatus; but this is rare. If a sinus be torn, the blood more often finds its way toward the brain than toward the scalp. Still, the opposite is occasionally true, as in a case (R. V. H., Surg. No. 8107, Path. No. 86, 1903) in which the lateral sinus was lacerated by an occipital fracture. Here the blood was effused entirely outside the dura and found its way through the fracture and into the deep tissues of the neck, where it appeared as an ecchymosis several days later. Such is the ordinary origin of ecchymosis appearing in the neck. But frequently the effect of bleeding in the subtentorial space is so inimical to life, because of direct pressure on the adjacent medullary centres, that death supervenes before any such extravasation of blood has time to appear in the neck.

c. Signs Dependent upon the Escape Externally of Intracranial Contents.—(1) The Escape of Cerebro-spinal Fluid.—When this occurs it is naturally pathognomonic of a fracture. It is, however, a comparatively rare event. Anna Heer (*von Bruns' Beiträge*, 1892, Bd. IX., page 1) found it only 4 times in 58 cases, twice from the nose and twice from the ear; while Crandon and Wilson in 530 cases noted it only 27 times.

A clear fluid escaping from the ear is not always cerebro-spinal in nature. If it be not great in amount, it may come from the membranous labyrinth (liquor Cotunni), or represent a reactionary exudate from the tympanic or nasal mucosa. It has been said that a chemical examination will settle the diagnosis. Cerebro-spinal fluid is rich in chlorides, but is without albumin, and contains a trace of a reducing substance allied to pyrocatechin; while fluid from other sources contains much albumin, a small amount of chlorides, and no reducing substance. As Rawling points out, however, such an examination may be vitiated in several ways. The cerebro-spinal fluid may be mixed with blood and so contain albumin; on the other hand, the reducing substance soon disappears from it, if the flow be profuse.

One must remember that in most of these cases there is present some degree of cerebral compression from intracranial hemorrhage, with consequent hindrance to venous outflow. (See section on Compression.) Now, as Leonard Hill showed, the normal escape of cerebro-spinal fluid is directly by the veins; therefore, this path being blocked or partly blocked, the fluid will take the path of lesser resistance through an open fracture, until nature closes the gap. Moreover, the cerebro-spinal and intravenous pressure being approximately equal, any material lowering of the former by escape of the fluid must induce a direct transudate from the veins and capillaries to restore the balance. Under such conditions the fluid soon loses its character of a secretion and becomes a mere serous exudation. The discharge, however, clinically speaking, may be assumed with certainty to be cerebro-spinal fluid if it be profuse and persist for some days; if it be small in amount and cease soon, doubt is justifiable. The date of its onset is rarely immediate, but usually within the first twenty-four hours. Instances are on record of its first appearing days, even weeks, after the accident. In duration it varies from a few hours to many days, and its quantity from a few ounces to several pints. In one of Sir William MacCormac's cases, quoted by Rawling, three pints escaped in five hours. von Bergmann estimates the average loss in twenty-four hours at 150–200 grammes (4 to 6 ounces), though, as he adds, it may very greatly exceed this amount. Its escape through the nose may result either from a break of the cribriform plate of the ethmoid, the more usual event, or (by way of the Eustachian tube) from a fracture of the petrous portion, or, again, from a fracture of the sphenoid body.

In the case of the flow from the ear, Rawling distinguishes two main varieties of fracture: "A fracture of the middle fossa with such comminution of the petrous bone that the subarachnoid space is opened up, either directly through the tegmen tympani or indirectly by involvement of the membranous prolongations along the seventh and eighth nerves; or a fracture of the posterior fossa, which, on reaching the jugular foramen, cuts across the petrous bone, traversing the vestibule and severing the facial nerve in the region of the genu. The external signs of injury and the condition of the facial muscles will generally suffice to make clear which variety of fracture is present."

(2) The Escape of Cerebral Substance.—The escape of cerebral substance is naturally an unmistakable sign of fracture, yet one hardly seen save under most severe trauma, where the diagnosis is already plain enough. It has been seen to come both through the ear and through the nose, but much oftener from the former than from the latter. The roof of the external auditory meatus is thin, and the base of the temporal bone lies immediately upon it.

A word may be spared to call attention to one further peculiar diagnostic sign, the emphysema of the mastoid region in fractures of the mastoid process. While pathognomonic, it is very rarely present. It may be sufficient to spread down over neck and thorax. Of course, the air comes from the mastoid cells.

d. Symptoms Dependent on the Lesion of Cranial Nerves.— It must be premised that any one of the basal nerves may be paralyzed, in the absence of all fracture, by pressure from blood-clot or inflammatory exudate, or by a lesion of its nuclear origin in the brain. Therefore, such a paralysis, save in the case of certain nerves and in conjunction with other phenomena, can possess only a relative value in diagnosis.

Basal fractures not infrequently pass through the foramina that give exit to the cranial nerves, and in the case of certain of these, such as the first, second, third, and sixth, through the bone that lodges them in their course along the base. Under such circumstances the nerve may be nipped by the elastic return of the edges of a bursting fracture, a rare event; or lacerated by a displaced spicule of bone; or, most frequently, torn across, sometimes only stretched, by the bursting action of the same violence to which the fracture itself is due. The paresis or paralysis from such accidents is of course immediate; but there is occasionally seen also a late paralysis appearing after some days, which is due to some infection with consequent ascending neuritis.

Undoubtedly the nerve most frequently paralyzed is the facial, as indeed one would expect from its long course in the petrous portion, as well as from the great frequency with which this bone is fractured. Rawling, in 60 cases, found it 24 times, and Kohler 22 times in 48 cases. Bidwell, Battle, and Anna Heer give much lower figures: 15 in 106, 15 in 168, and 10 in 58 cases. Crandon and Wilson in 530 cases found it 46 times. They state that in all but two or three it appeared from three to six days after the injury, and the paralysis was usually of short duration. Where recovery is rapid, one must assume that the palsy was due to reactionary œdema. It is possible that slight degrees of facial paresis are frequently overlooked; indeed, it needs a certain training in neurological examination to discover the slighter grades. A very careful comparison of the two sides is necessary, exact note being taken of slight differences in the facial wrinkles, in the degree of resistance to the pulling open of the "screwed-up" eyes, and so on.

Rawling feels justified in distinguishing two distinct grades of facial palsy corresponding to two different lines of fracture. In the one the fracture runs in the longitudinal axis of the petrous portion, as occurs in most middle-fossa fractures, passing through the internal ear and inward to the region of the petro-sphenoidal suture, so as to lay bare the geniculate ganglion of the facial on the anterior aspect of the posterior fragment. "The main trunk of the nerve consequently escapes injury, except in the region of the genu, where it may be compressed by blood-clot sufficient to produce a partial temporary loss of function. In most cases the clot is entirely absorbed, and a complete recovery can be expected." With this fracture one will frequently observe bleeding from the ear. In the second class the fracture runs in a direction more or less at right angles to the first, proceeding in an antero-posterior line through the cerebellar fossa and across the petrous portion external to the internal auditory meatus, ending usually by comminuting the tegmen tympani. The result is that the "facial is cut clean across in the region of the genu, and the auditory apparatus also is severed into two parts." Here there is naturally no bleeding from the ear, and the paralysis is permanent. The violence is usually occipital.

How far such a classification is justified is problematical; yet it seems to hold good in many instances.

The eighth nerve is nearly always injured coincidently with the seventh. And Rawling, in the distinction just drawn in the lesions of the facial, includes the auditory as being subject to a parallel degree of injury, with similar outlook as to recovery or the contrary.

There occur, however, with some frequency, disturbances of hearing which are the direct result of cranial violence and are nevertheless unaccompanied by basal fracture. Rhese,* in a late article, has investigated, from the standpoint of the expert aurist, the lesions of the auditory apparatus in cases of pure concussion consisting chiefly in a loss of perception of the tones at the extremes of the tuning-fork scale. Their demonstration demands expert investigation. von Bergmann, too, refers to an article by Kaufmann in which it is suggested that violence may induce hemorrhage into the labyrinth, or lesions of the auditory perceptive centres or their projection paths to the periphery.

The sixth nerve is quite frequently paralyzed, either alone or in conjunction with the other nerves near the cavernous sinus. When it is affected alone we may suppose a direct local injury in its course along the side of the dorsum ephippii. In view, however, of its very frequent and isolated paralysis in all sorts of conditions attended by intracranial tension, notably with tumors, and quite apart from any local pressure, I cannot help thinking that the same explanation as is offered in these cases, that of a stretching of the nerve in its long straight course, must apply also where, as here, the cranial capacity is diminished by effused blood.

The paralysis of the other nerves is so rare that we may content ourselves with indicating their occurrence and effect. The olfactory may be involved in fractures of the orbital plates, and anosmia is not rare at first, yet is rarely permanent. The optic nerve nearly always escapes, as fractures run either between or outside of their course into the optic foramina. In the experience of the Royal Victoria Hospital, I have found only one instance of permanent lesion of the optic nerve. The patient's head had been crushed between two cars, being gripped on both sides in the temporal region, with the result of a pure bursting fracture. A late examination, eight years after the accident, reveals total blindness, together with almost complete loss of smell and marked loss of taste. Here, plainly, the first and second nerves were both torn across.

The nerves which pass along the cavernous sinus and through the sphenoidal fissure, the first division of the fifth, the third, the fourth (and the sixth, already referred to), may be damaged by fractures of the sella turcica and the orbital plates, but are rarely completely paralyzed. The second and third divisions of the fifth are very rarely hurt save as part of an injury to the Gasserian ganglion by a fracture running through the cavum Meckelii.

The ninth, tenth, and eleventh nerves, taking their exit through the jugular foramen, which is not infrequently traversed by basal fractures, might be expected to suffer correspondingly frequent injury. Yet this, curiously enough, is rarely the case; they usually escape. Now and again, however, one may come across instances where quite plainly the jugular foramen has been broken,

* Deutsche medizinische Wochenschrift, Apr. 19th, 1906.

and the resulting clot, if not a bony splinter, has pressed upon the nerves, with the consequence of definite symptoms.

Thus, a student while playing football came down heavily in the sitting posture. He got up, ran a few yards down the field and back, and then lay down, realizing that he was hurt; and was shortly unconscious. During several days the only sign of cerebral compression, apart from deep unconsciousness, was an extremely slow pulse, which was for a while as low as sixteen. Breathing was undisturbed. The eleventh and twelfth nerves were unaffected.

Such an observation can hardly be interpreted save as the effect of a temporary compression of the vagus. It may be added that the patient's recovery was uneventful and the cure permanent. Rawling relates two cases in which acute dyspnœa and dysphagia were the chief symptoms.

The twelfth nerve, as far as I can find in the literature, has not been involved in basal fractures.

Naturally, fractures of the skull are frequently accompanied by meningeal hemorrhages and various lesions of the brain substance. These will be discussed in the section upon Injuries of the Brain.

Clinical Course of Fractures of the Skull.—In the eighteenth century the necessity of trephining for a fracture of the skull, even if it were but the merest fissure, was regarded as a surgical truism. Nowadays it is equally a truism that the gravity of a fracture depends, not upon the fact of the anatomical solution of continuity, but upon the coincident damage to the brain, traumatic or inflammatory, of which the fracture is the direct cause. And we know that the greater mortality attendant upon basal as compared with vault fractures is due, not to any essential difference in the character of the fracture itself, but to the greater damage done to important vessels and the more vital areas of the brain lying at the base. The coincident cerebral and meningeal lesions will be discussed in the sections on Cerebral Compression and Injuries of the Brain. Here we may consider:

The Repair of Skull Fractures.—The essence of this matter may be told in few words. Probably nowhere else in the body does broken bone, as a rule, repair itself so poorly as in the skull. Provisional callus is usually lacking, and the definite callus of comparatively small amount.

It would be an error to conclude that this is due to any lack of capacity on the part of the cranial tissues to produce bone. Indeed, the contrary is indicated, as von Bergmann points out, by "the exostoses and hyperostoses, the osteophytes seen in pregnancy and the puerperium, the diffuse osteosclerosis and the filling in of extensive bony defects resulting upon necrosis of the cranial bones." To which might be added the extraordinary thickenings seen in cases of syphilis and of malignant disease. In all these it is evident that the common factor is a stimulus or irritation of some sort, known or unknown. And in the fracture of other bones, all characterized by nature's usual exuberance of repair tissue, we find a common factor in the irritation of mechanical friction due to the frequent slight movements of surrounding muscles. This factor is the one that is lacking in fractures of the cranial bones. Their anatomical rest is practically absolute, there is no movement of the fractured edges upon each other from the involuntary play of attached muscles.

Thus the formation of callus in these cases is slight; it does not usually exceed the limits of the periosteum, and union is slow. It is a generally accepted fact that the dura and the diploë are the chief makers of new bone, while the external periosteum does but little. Certainly in cases in which an opportunity, say from a fatal abscess following a fracture after some weeks or months, is given to observe the course of healing, one may observe, according to von Bergmann, a slightly excessive production of bony callus on the internal surface; yet this disappears completely, and ultimately the condition usually found is a denser, more solid, yet even union between the inner tables with a slighter and occasionally imperfect union of the external. von Bergmann states that, "with long gaping fissures, it is the rule that the depths only of the fissure become filled with callus."

In a patient from whom I removed the greater part of the frontal bone over the forehead, leaving the dura exposed (see Fig. 13), it was interesting to note that the defect was gradually filled in to a large extent by new bone which plainly grew from the internal table and dura, the external remaining inactive. Another clinical example of this fact lies in the frequent reunion of splinters of the internal table that have been torn from their connections with the diploë and the dura. Yet, not infrequently the fissures may remain quite unfilled by new bone, particularly in the case of children, as has already been mentioned.

As to the repair of actual cranial defects, of loss of substance, the evidence is more or less contradictory. The conclusion, however, of the majority of authors is that the larger the defect the less will it be filled in. "A complete bony repair of the larger defects is a rarity, and is not to be expected in the case of a loss of substance of 6–8 cm. [2 to 3 in.] square and over." Yet Kuester reports an instance of very large defect completely filled in after twenty years; and in the writer's case, just mentioned, the gap in the frontal bone has become reduced in the course of three years to very small proportions. Trephine openings, even large ones, I have occasionally seen close completely in the course of time. Healing in of bone fragments, such as a trephine button replaced whole or in pieces, has been frequently enough recorded. But in such instances, as Barth proved, it is fairly certain that the bone replaced did not live, but served merely as a framework to guide and receive the ingrowth of bone tissue from the surrounding living bone.*

Treatment of Fractures of the Skull.—(A) *Fractures of the Vertex.*—

* Barth: "Histologische Befunde nach Knochenimplantationen." Verhandl. d. Deut. Gesellsch. f. Chir., 1893, xxii.

The interest attaching to simple fissured fractures of the skull relates far more to the mechanism of their production than to their treatment. Such lesions, regarded simply as fractures, demand practically no treatment, and what treatment is given will be found upon analysis to be directed, not toward the healing of the bone, but toward a warding off of damage to the brain, or bringing a remedy for what damage may already have been done. And this indeed is true of all the varieties of cranial fracture, save those accompanied by actual loss of substance.

The damage may be of two kinds: (1) Injuries to vessels of the meninges, and the brain itself; (2) infection of the meninges or brain. Thus the treatment of cranial fractures may be summed up in a few words. If they are simple, leave them alone, unless there be reason to believe that the brain is being injured by bone fragments or dangerously compressed by effused blood. If they are compound, make the wound surgically clean in order to avoid infection of the brain or its membranes.

If surgical interference prove necessary, the principles involved are those of modern wound treatment in general. There are, however, particular circumstances which deserve more detailed consideration. In the first place, a fissured fracture of the convexity without wound of the soft parts and without evidence of serious cerebral compression, will always be let severely alone. The disagreement among surgeons has always concerned in particular the depressed fractures. A depressed fracture of the vertex will usually be complicated by a wound of the overlying scalp, from the very nature of the instrument that ordinarily causes this variety of fracture. In such cases the rule will hold, that interference is demanded with the object of raising the depressed fragments, securing hæmostasis, and, above all, making the wound surgically clean.

Naturally the danger of infection varies enormously according to whether the dura be wounded or not. It is not to be supposed, however, that the danger of meningitis or of cerebral abscess is quite excluded by an intact dura. Suppuration outside the dura may easily lead to either complication by the process of direct extension through that membrane, as is shown by the whole history of otogenic meningeal, and cerebral infections. And I have in mind a patient suffering from traumatic epilepsy, trephined in the frontal region with opening of one frontal sinus, who in the event died of an intracranial abscess, the dura having been left unopened. And there are also the not infrequent instances of cerebral infection from an erysipelas of the scalp or a cranial osteomyelitis. Therefore, whether in these cases of compound depressed fractures the dura be injured or not, the duty of converting a probably infected wound into an aseptic one lies heavy on the attending surgeon; and the operation in consequence must be a painstaking one.

This means, in my opinion, not the mere washing out with antiseptic solutions and picking out of visible foreign bodies, but rather the cutting away of the whole edge of the wound whenever the latter is soiled with dust or dirt of any kind, or when crushed or otherwise devitalized; and also the removal, with rongeur forceps or chisel, of the bone edges where any possibly infective material has been driven into it. Only so can we reasonably hope for aseptic healing where aseptic healing is of more importance than anywhere else in the body.

But if there be discovered a depressed fracture without wound of the scalp, what course are we to pursue? The danger of infection is practically out of the question. But what about the brain? Here von Bergmann makes a distinction. If the depression be in one piece, that is, not splintered, he advises leaving it alone, the argument being that (1) no limited bone depression is sufficient in itself to compress the brain seriously; (2) possible infection is avoided; (3) the subsequent danger of epilepsy is no greater than from the scar which would result from the operation of raising the depressed bone; for epilepsy develops as often in cases of fracture without as with depression. On the other hand, he continues, if the fracture be a splintered one, one of the fragments may be driven inward through the dura mater and into the brain substance. If now this fragment involve the motor region, it may be recognized by local paralyses, and under such circumstances should be removed by operation because it acts as a continuous focus of irritation, even of actual trauma, to the pulsating brain.

To this we may answer that von Bergmann's limitation of diagnosable pressure from a bone splinter to the motor region is unjustifiable in these days of finer localization, and that the field of operation is thus greatly widened. But apart from this consideration it may be said that the consensus of surgical opinion at present is to raise every depressed fracture that can be diagnosed as such, unless it be of extremely slight extent; and this for the simple reason that the internal table is always broken more extensively than the outer, and that it is impossible to say from palpation or even inspection of the latter that there is not a splinter from the internal table driven at an angle into the brain. In such cases the danger of subsequent epilepsy is certainly sufficient to justify the operation.

A further question, long and closely debated, is that of the reimplantation of such depressed fragments as are broken loose from their blood supply, or of the button of bone removed in trephining. It may at the outset be admitted that the filling in of a cranial defect is desirable. The argument, however, has run along two lines: (i) Is the immediate restoration of bone covering really necessary? (ii) Will the fragments, if replaced, heal in? My own opinion is to the effect that the deciding factor, quite regardless of these two considerations, should be the likelihood of infection. If the fracture is not compound and operation is being done through intact skin, the fragments may be replaced. If it is a compound fracture and the wound contains fragments of hair or of the headgear, or if it were inflicted by a blunt and, surgically speaking, dirty instrument, then loose splinters should not be replaced, and the wound should be left more or less open for drainage. Complete primary closure of the wound is justifiable only in exceptionally clean wounds, and the surgical cleansing of a grossly infected wound can hardly ever be so certain as to justify dispensing with ample drainage. Friedrich has shown that suppuration is encouraged by restoring the mutual tension of tissues, as is done by complete closure; and is discouraged by all lack of tension, as in open wounds.

In spite, therefore, of the fact that many cases are on record of the healing in of replaced bone fragments, I believe that the surgeon will follow the safer course in leaving them out, for if infection occur they are apt to help in confining the pus. On the other hand, the ultimate repair of small bone defects is likely to occur by regeneration from dura and internal table; while, even in the contrary event, a very firm closure is still obtained from the firmness of the scar tissue that fills in the gap.

In carrying out the cleansing of the wound along the lines indicated, it is important to lay widely open all recesses under undermined skin, making, if necessary, free incisions. If the wound be already infected when the case comes under observation, the general surgical principle of free incisions must obtain here as elsewhere. To give free exit to pus, all sloughs or fragments of bone under which pus has collected or may collect must be removed, and liberating incisions made in infiltrated soft parts. Even where a local meningitis is already present, such treatment will not infrequently succeed in preventing its becoming generalized. Wagner, out of twelve cases already infected on admission to hospital, was able to save eight by pursuing these principles of treatment.

(B) *Treatment of Basal Fractures.*—Here, as in vault fractures, treatment must be determined by the two possibilities of cerebral injury and infection. The latter is to be feared, generally speaking, only in such fractures as invade the orifices of the head, the ears, and naso-pharynx. In the text-books of the earlier days of antisepsis, when over-great faith was placed in the germicidal power of antiseptic solutions, it was usually advised to syringe out the nasal or auditory passages with carbolic or bichloride lotions. It is now recognized that such prophylactic measures carry with them more danger than they prevent, inasmuch as the stream of irrigating fluid may bear into the depths of the wound organisms that it fails to kill. On the other hand, it is decidedly indicated to cleanse as far as possible the external passages, at any rate the auditory canal, by means of swabbing with gauze or cotton wet with an antiseptic lotion.

The nasal and naso-pharyngeal area is much less accessible, and I do not think there is any real use in even swabbing these parts, save in so far as it is necessary to prevent damming back, and to secure the free outflow, of blood or cerebrospinal fluid. Stagnation should be prevented, if possible. Loose strips of aseptic gauze may be kept in the ears to absorb the discharge of blood or fluid, but they should never act as a plug, and they should be changed frequently. Their use in the nostrils is less desirable on account of the tendency of all foreign bodies, when kept in contact with a mucous surface, to excite catarrhal inflammation. More than this it will rarely be necessary to do, save in those cases of compound fracture situated so low as to involve the base, as, for instance, in crushes of the zygomatic region; here the operative procedure of cleansing the wound and removing splinters must include naturally any basal territory that is injured. What has been said under the heading of Vault Fractures is here equally applicable.

If bleeding from ear or nose be so persistent and abundant as to become threatening, one will naturally be obliged to pack these cavities firmly, yet not before the question of exploratory operation has been thoroughly considered. In the case of such a hemorrhage from the ear there is, according to Rawling's opinion, a reasonable probability of meningeal hemorrhage, sufficient to justify exploratory craniotomy even in the absence of other more distinctly diagnostic symptoms. If the packing of the ear evidently increases intracranial tension, it may be concluded that the source of the hemorrhage is meningeal, and operation would then, at least, be plainly indicated.

In the subsequent course, both of vault and of basal fractures, which have been complicated by infection, it becomes occasionally necessary to remove small sequestra, and most frequently perhaps in cases of basal fracture involving the middle ear or mastoid. It may even be necessary to do a complete mastoid operation. The existence of deep sequestra is suggested by the persistence of suppuration.

(4) *Punctured Fractures.*—These are to be considered more or less in a class apart. In the manner of their causation, in their course and results, and in their treatment they offer essential differences from the fractures which have hitherto been discussed. A salient point is the frequency with which they are overlooked; and the reason of this lies in the manner of their production. The wounding instrument punctures the base of the skull through one of the orifices—orbit, mouth, pharynx, or nose; and, when it is withdrawn, the physician is apt to imagine that the depth of the puncture is not great, and that the superficial injury represents the whole matter. In other instances the instrument enters the cheek underneath the zygoma, passes up under the zygomatic arch, and penetrates directly into the middle fossa. Here too the same remark is applicable. The appearance of the superficial wound is often misleading; it may be very trivial, and at a considerable distance from the opening in the skull. The whole affair is usually of such rapid occurrence—the instrument is forced in and pulled out so quickly—that it is difficult to think that the brain has actually been penetrated.

It is necessary, then, to suspect all wounds of this character of having entered the skull; and, this suspicion once aroused, it is further necessary to suspect the retention of a part of the wounding instrument. The physician must always demand to see the latter, and determine with his own eyes whether a portion of it has been broken off or not. For instance, one finds recorded cases where there have remained pieces of lead pencil, wood, tobacco pipe, a brass ferrule, the blade of a penknife, etc., embedded in the wound.

One might think that cerebral signs of one sort or another would inevitably betray the fact of a perforation of the base and wounding of the brain; but such is very frequently not the case. It must be remembered that the majority of the wounds are in the region of the orbit, and that injury to the frontal lobes may often be perfectly well tolerated without symptoms. Under such circumstances, and with the swelling of the superficial tissues, especially those of the orbit, exploration is rendered most unsatisfactory, and it may be almost impossible to determine the mere fact of a punctured fracture of the base.

Once the instrument has penetrated, one must be prepared to expect a wound of almost any depth in the soft brain matter. Knaggs* reports one instance in which an iron bar penetrated from base to vertex, the patient dying some days afterward. In a case observed by the writer, a child, playing diabolo, drove one of the little bamboo rods through the orbit, and, to judge from the symptoms, at least two inches into the brain. The wound was on the left side, and he developed, within a few moments, aphasia and right hemiplegia. The stick therefore must have penetrated through the whole left frontal lobe and reached the motor fibres in the corona radiata. This boy recovered perfectly in a couple of months save for a slight contracture of the arm.

Such a fortunate result is very rare. Of eleven cases collected by Knaggs, all but two died; of the nine, six succumbed to meningitis, the rest to hemorrhage, abscess, and septicæmia.

While the diagnosis may often be difficult, the indications for treatment are not less so. These will depend, in the writer's opinion, chiefly on the question of infection. There is to be suspected in the majority of cases a very definite possibility of this complication; and it becomes a question whether one should or should not do an extensive exploratory operation in order to trace the track of the wound, and to lay it open in the hope of guiding to the surface any pus that may have formed. Where the damage is great, where, for instance, the eyeball is disorganized and the outside wound considerable, such a procedure will be undertaken without any hesitation. On the other hand, where the instrument has been small and narrow, where it is presumably clean, though not entirely aseptic, as in the author's case where the instrument was a small bamboo rod, one will, I think, prefer to adopt an expectant plan. Even if it were possible to make a large window in the skull at the base and to drain that area and the wounded meninges, there would remain still the danger of intracerebral abscess; for such a wound in the brain tissue itself can certainly not be

* "Punctured Fractures of the Base of the Skull." Lancet, June 1st, 1907.

drained. Where the wound has taken place through a cavity which is septic, such as the nose, mouth, or pharynx, there is the greater indication for operation, but the less hope of doing good. The injury to the base is situated in an inaccessible region, and to follow its track may easily be not only useless but harmful. In such instances, save perhaps in hospitals, one must trust to good fortune, and, unfortunately, often trust in vain. One or two cases are on record of successful draining through a frontal trephine opening.

Gunshot Wounds of the Skull.—The fractures caused by gunshot wounds have already been admirably described in a general way by Major Borden in the second volume of this System. I wish, however, to discuss here certain aspects of the subject in a little more detail.

In gunshot wounds, except those from very small firearms, some lesion of the brain accompanies that of the skull with such regularity that it becomes really necessary to include their discussion in one and the same chapter. Leaving aside for the moment the smaller firearms, we may consider first, and chiefly, the wounds inflicted by the modern army bullet. The changes in the army rifle and bullet during the past twenty years have brought out numerous experimental investigations as to their effect upon human tissues, and particularly upon the cranium and its contents. The enormous velocity and the penetrating power of the modern jacketed, cylindro-conoidal, small-calibre bullet produce wounds quite different from those to which military surgeons of a previous generation were accustomed.

While the injury to skull and brain from firearms varies greatly through a long scale, depending to a certain extent upon the shape and hardness of the bullet, yet it is evident from the long list of experiments that the main factor to which the variations in lesion are due resides in the velocity of the missile at the moment of impact. Yet, of great importance also, as explaining the degree of the damage done, is the nature of the object struck. This is, of course, practically constant. The cranium is a closed and somewhat rigid ovoidal or spheroidal box, filled with a substance that is semifluid and incompressible. The mode of fracture will depend upon the shape and structure of the skull and the nature of the violence; while the damage to the brain will be the result of the transmission of force from a rapidly moving object to an incompressible substance.

Nature of the Injury Inflicted by the Bullet.—The modern bullet possesses three qualities of action: by its propulsion it delivers a blow, by its rotation on its long axis it drills, and in virtue of its conoidal shape it splits like a wedge. Considered broadly, these three modes of violence may be traced in the character of the resulting cranial lesions.

One may distinguish, with Nimier,* three degrees of violence: contusion alone, penetration with or without perforation, and the explosive effect.

* "Blessures du Crâne et de l'Encéphale par Coup de Feu," Paris, Felix Alcan, 1904.

a. Contusion of the Skull without Penetration.—The bullet that is nearly spent, or has but little velocity, delivers a blow, but has not enough force to bore through or split. The effect on the skull, therefore, resembles that of a hammer, and the resulting lesion does not materially differ from that described under the general heading of Bending or Impression Fractures. There occurs the zone of depression followed by the elastic return. The violence, if slight, may produce no more than microscopical changes in the bone elements; when it is greater, but not

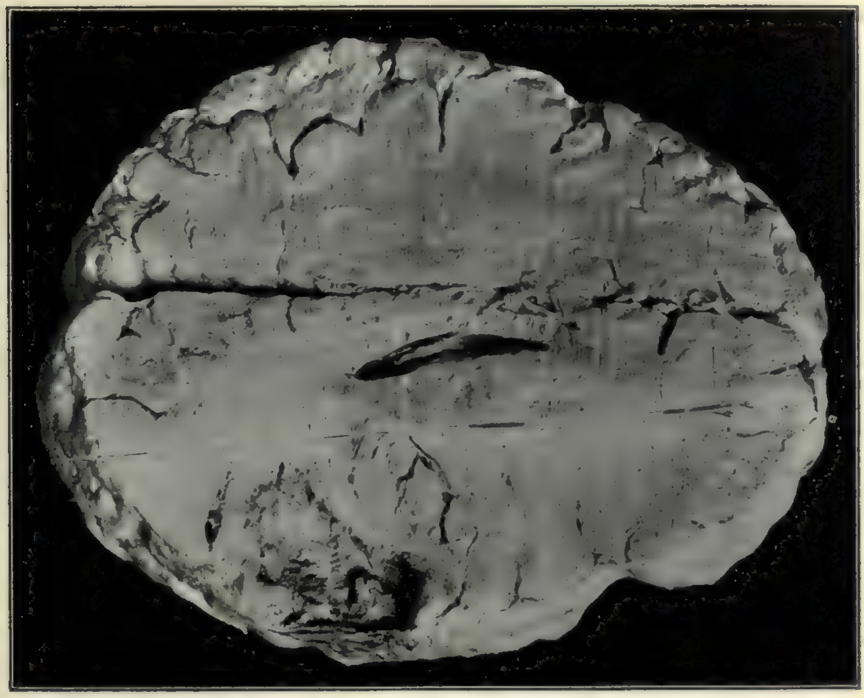


Fig. 24.—Destruction of Temporo-sphenoidal Lobe from Bullet Wound without Perforation of the Skull. (From the McGill Pathological Museum, 73, 81, 1.)

sufficient to produce penetration, one will find all degrees of depression with inbending fractures, combined frequently with fissures from a bursting effect. To my mind it is undoubted that such a localized violence as that of the bullet may and does attack the elasticity of the skull as a whole, as a hollow ovoid body; and consequently that it brings into play the bursting principle. The experiments of Bohl upon the effect of a blow on the free-hanging skull, and of Braquehaye, have already been cited in this connection. Thus one finds with varying degrees of violence a slightly depressed external table with more or less extensive fissuring of the internal one; localized fissuring of both tables; fissures radiating to considerable distances; and occasionally isolated fissures of the weaker parts of the base, especially the orbital plates, evidencing the influence of the bursting effect along the whole extent of the meridian.

As the impress of the violence is more or less circular, the depression is cone-shaped, and consequently the fissures, especially those of the first-broken internal table, are apt to radiate regularly from the point of the cone of depression like the spokes of a wheel. When, as is usual, there occurs a ring fracture, this combination of fissures yields a rough picture of a wheel, the "fracture en roue" of the French. The radiating bursting fissures frequently extend well beyond the rim of the wheel. All this applies to instances of perpendicular impact. If the blow be tangential there is usually but one fissure, which runs parallel with the direction of the shot.

In the section on Concussion there is described the effect on the brain of a blow upon the skull. Whether or no the skull yield, the force of the projectile, by elastic inbending of the zone of depression, is transmitted to the underlying brain, which receives a definite blow, so that the pial vessels may be torn, and even the cerebral substance itself lacerated. Of this, our museum affords a beautiful example. (Fig. 24.) A revolver shot had caused, in the right temporal region just above and behind the ear, a ragged wound, evidently tangential. There was no fracture of the skull nor wound of the dura. Yet there was found in the right temporo-sphenoidal lobe a softened hemorrhagic area of the size of a hen's egg, in which the brain substance was pulpified. In the vicinity there were typical contusion lesions. Similar instances are to be found scattered through the literature.

b. Penetration with or without Perforation of the Skull.—When the ball penetrates the skull, its effect goes beyond that of the mere blow and becomes that of a drill and also of a wedge. The boring or drill effect is not prominent, save in tangential wounds; it means an actual loss of bony substance, the enormous velocity of rotation cutting out the bone as does a fraise or a dentist's drill.

In these glancing wounds the shape of the fracture is frequently characteristic. The ball ploughs a gutter in the bone, the two ends of which are shallower than the middle. The skull may or may not be completely perforated in the depth of the furrow; but in either case it is practically certain that the internal table will be fissured or even fragmented, just as in ordinary depressed fractures, because even a glancing bullet delivers a blow through transmission of part of its force laterally. Therefore one must be prepared for some degree of cerebral injury even in the non-perforating tangential wounds.

When the ball strikes perpendicularly, the effect upon the skull's structure is peculiarly a combination of the bursting and the wedge actions. The latter is seen in its perfection in such cases as that of von Bergmann, already related, in which a fragment of bullet was found inside the skull with practically no trace of its point of entrance; here the bullet had wedged or insinuated its way between the bone elements, and after its passage the edges of the fissure had sprung back elastically to their former position. It is seen, also, though in a less degree, where the wound of entrance is smaller than the calibre of the bullet.

Of the fissures radiating from such wounds, at least two or more represent the splitting effect of the wedge; the rest are bursting fissures. (See Fig. 25.)

In a general way these run parallel to the direction of violence. Nimier calls attention to certain of them that appear with great regularity. Thus, where the bullet penetrates the frontal bone he finds a transverse frontal fissure which runs round on both sides above the external angular process and down into the

Fig. 25.—Bullet Wound of Frontal Bone, Showing Multiple Radiating Fractures, Illustrating both the Bursting and the Wedge Actions. (From the Pathological Museum, McGill University.)

temporal fossa. (Fig. 25.) Here, at almost symmetrical points, the fissure bifurcates; one branch continues round the vault, tending to meet the other at the occiput, while the other descends to the root of the zygoma, involving the auditory canal and ending in the mastoid. The former tends to separate the vault from the base, the latter the bony framework of the face from the cranium. On the other hand, where the bullet passes from side to side, the chief bursting fissure runs through the base and over the vertex, and is apt to divide the cranium into anterior and posterior halves. Occasionally, it is true, the other meridian, the horizontal one round the skull, is elected by the bursting force (see Fig. 26); and the skull, as in fronto-occipital violences, is divided into upper and lower halves. This is well seen in Mr. L. B. Rawling's case, related in his Hunterian lectures.*

As to the wedge effect, naturally the more angular the impinging surface of the bullet or the fragment of shell or other similar missile, the greater will be the number of wedge fissures. A chisel causes but two fissures, one from either side. A pointed triangular wedge will cause three, and so on. How many

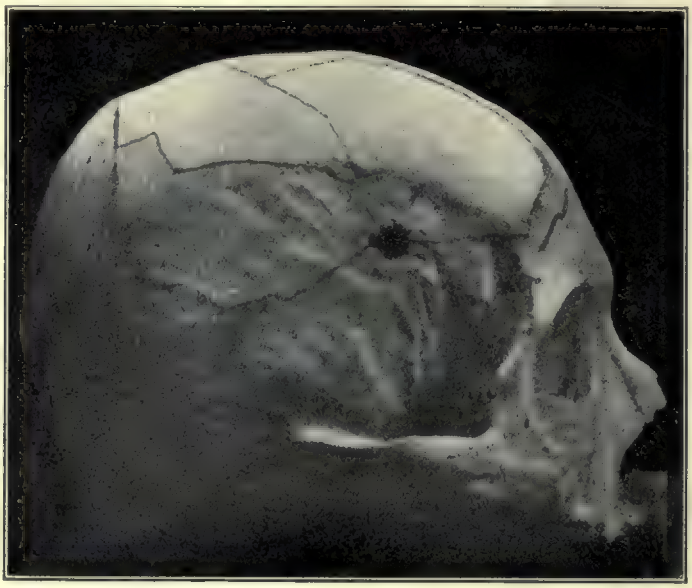


FIG. 26.—Perforating Gunshot Wound of Cranium. Lebel ball at 400 metres. Wound of entrance. Note its small size and nearly circular outline; also the radiating lines of bursting and wedge effects. (Nimier, in Chipault's "État Actuel de la Chirurgie Nerveuse," Vol. I., p. 58.)

the bullet with its conical end will produce must remain unknown, as they are necessarily mixed with and masked by the fissures which are due to bursting.

The study of the fractures seen in a skull as the result of these perforating gunshot wounds shows a steady augmentation of the fissuring action parallel with the augmentation of the bullet's velocity; in other words, with the lessening of the range. One finds in the lower grades of severity two "hole-fractures" without fissures; in the highest grades, such a fissuring of the entire vault that the skull under the scalp feels like nuts in a bag, or even that the skull-cap is blown completely off; the skull is "exploded"; between these extremes one sees combinations of radiating and circular fissures in which can be easily traced the bursting and the wedge effects.

* Lancet, April 9th, 1904.

The explosive effect is seen only at very short distances, not above 50 metres. Beyond 2,000 metres the two holes without fissuring are the rule; but under 2,000 metres one sees appear first one or two bursting fissures joining the two apertures; then at a distance of about 1,600 metres there develops in addition the circular or ring fissure (see Fig. 27), surrounding at a short distance each of the holes, due to inbending and outbending action (Treub's Flachbiegung and Krummbiegung), as in the ordinary depressed fracture, which indeed it is. Thus, in clear cases, one will see two "wheel" fractures (Fig. 27), one at either

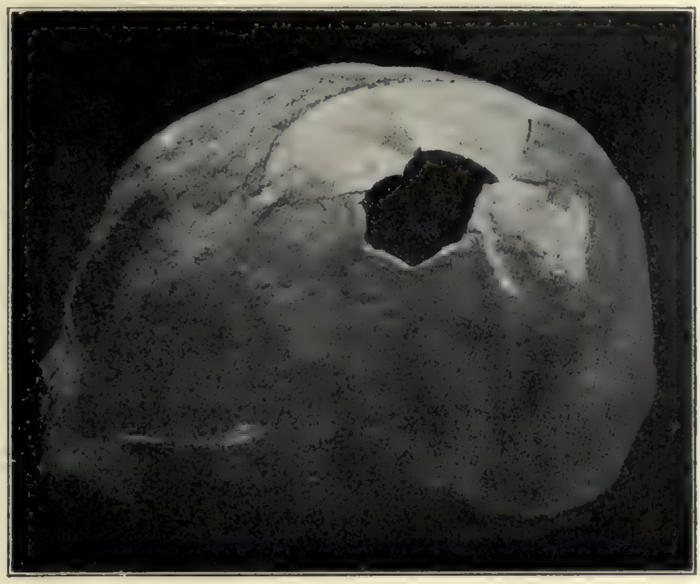


Fig. 27.—Perforating Gunshot Wound of Cranium. Lebel ball at 400 metres. Wound of exit. Note its large size and irregular shape as compared with that of entrance. Note also the circular line of fracture ("ring" fracture) as well as the radiating fissures, which together make up the "wheel" fracture. (Nimier, *loc. cit.*, p. 59.)

end of the diameter of violence, between which run one or more radiating fissures. This type becomes more and more evident as the range shortens, and is fairly regular at 800 metres.

At still shorter ranges this quite distinguishable combination of the bending, bursting, and wedge fractures, becomes gradually lost in a perfect maze of fissures, the longitudinal bursting ones being crossed at all possible angles by modifications of the circular and oblique outbending type. Isolated or continued fractures at the base become more and more frequent. At 100 metres there is still discoverable some slight degree of regularity in these fissures; those originating in the wound of entrance can be distinguished from those of the wound of exit; and the two systems interlace over the vault, while some continue unbroken from one perforation to the other; a set of circular fissures can be seen to belong more particularly to each of the wounds. But under 100 metres, certainly under 50, all regularity is lost, the skull is broken as an egg-shell that is crumpled up.*

In practically all grades the wound of exit in the skull is apt to be larger than that of entrance, for the reason so well demonstrated by Teevan, and already quoted, that the break in the bone is always larger on the side of convexity, of distention. (See Fig. 27.) At short ranges, particularly with the not quite recent firearms, the wound of exit may be very large. Kipling, with his usual command of detail, tersely expressed it in "*The Grave of the Hundred Head*":

"A Snider squibbed in the jungle—
Somebody laughed and fled,
And the men of the First Shikaris
Picked up their subaltern dead,
With a big blue mark in his forehead
And the back blown out of his head."

Yet with the latest types of rifle, the hole of exit is also quite frequently small, 2 or 3 centimetres in diameter, though the skull and brain may be extraordinarily destroyed. This doubtless is because, in many cases, the scalp holds. Though the latter is badly lacerated, as a rule, it is only in the severest explosive effects that it is so disrupted as to allow the vault to be blown off.

The damage to the brain is also proportional to the velocity of the bullet. It seems to be mainly a question of the lateral violence transmitted by the missile in transit; the greater the velocity the greater the lateral violence. Thus at long range the brain is merely traversed and the destruction of tissue is confined pretty well to the path of the ball. At shorter range, the particles of nerve tissue receive from the bullet the impulse to movement in all directions, so that disruption occurs, a disruption which is naturally greatest near the track of the injury; and the result is a pulpifying and laceration of the tissue accompanied by numerous small and large ecchymoses. This actual destruction of nerve tissue and hemorrhage into it are by no means confined to the immediate track of the bullet, though of course most pronounced here, but are distributed, at least in the severest cases, pretty well over the entire brain, evidencing the generalized effect of the violence. The damage done is still further increased by the frequent import of bone spicules from the wound of entrance.

A part of the brain tissue, together with bone dust and bone spicules, is carried violently out by the bullet at the wound of exit. Very shortly, from the effusion of blood, cerebral compression develops, and brain matter is squeezed out of both openings, particularly the larger one of exit. The dura mater is torn in a manner similar to that which is observed in the case of the bone, though in less degree. It presents the two apertures made by the bullet, and also tears running usually between these two.

* Consult von Coler und Schjerning: "Ueber die Wirkung und kriegschirurgische Bedeutung der neuen Handfeuerwaffen, etc.," 1894.—Kocher. "Zur Lehre von den Schusswunden," 1895.

There remains to be described the third degree of cranio-encephalic lesion, that of explosion of the head.

c. The Explosive Effect.—When the bullet from a modern service rifle strikes the cranium with all its muzzle velocity of from 2,000 to 2,800 feet per second, the damage done is best described by the simple statement that the head is blown to pieces as by an explosion. The skull is broken into a multitude of fragments; the scalp is so torn that great ragged flaps fall outward over the face or neck; the whole calvarium may be distributed in pieces for yards around, together with portions of brain tissue, and the cranial base is fissured in all directions.

This represents the explosive effect of the modern rifle bullet upon tissues that contain a high percentage of water, and it was first properly explained by von Coler and Schjerning as being due to hydrodynamic pressure. According to the views of these authors, now universally accepted, the bullet upon penetrating with enormous velocity a tissue containing a high proportion of water gives off to the molecules of the tissue a part of the force inherent in its momentum. The greater the velocity the greater the "living force" inherent in the bullet, and the greater the amount of this force given off to the tissue through which it passes.

But more important than this in explaining the effects produced is the nature of the tissue traversed. The greater the proportion of water in a tissue the more incompressible it will be, as water is incompressible; and the more incompressible it is, the greater is the proportion of the force that it will take up unchanged from the moving bullet (whose force is expressed chiefly in movement, that is, momentum), and the less of that force will it expend in a condensation of its particles. The natural result is that the particles of a moist incompressible tissue accept the transmitted force more or less unchanged, that is, accept the force of movement as movement, and are themselves set in motion, a motion whose rapidity is as great as that of the bullet.

In this respect the cranium and the brain are peculiar. We have already discussed the effect of the bullet on the bone; its effect on the cranial contents is quite different, because they contain so much water as to be practically incompressible. Now, according to Pascal's law, "pressure exerted upon a mass of liquid is transmitted undiminished in all directions, and acts with the same force on all equal surfaces, and in a direction at right angles to those surfaces." Therefore the brain elements are immediately endowed with rapid motion in all directions. This rapid, violent flight of the tissue particles in all directions lies at the root of the explosive effect. It would, however, be erroneous to conclude that the extraordinary violent disruption of the brain substance in this fashion was the sole and sufficient cause of the explosive effect. It is doubtful if the brain itself, however great its momentum, could ever burst the skull into numerous fragments as we see it in such instances. The major factor in this is undoubtedly the action of the bullet upon the skull, producing bursting, wedge and bending fractures, with loss of substance at entrance and exit points. These are the direct result of the bullet's effect upon the cranial spheroid; yet it may be assumed that the violent outward propulsion of the brain mass assists in completing, possibly also enlarging, the fractures; and that, when these are complete, it drives before it fragments of detached scalp, bone, and brain matter, with the same force with which it is itself driven out, namely, the lateral and propulsive violence imparted by the bullet. In experiments upon empty crania such explosive effects are not observed.

Tillmanns* has demonstrated the explosive effect very ingeniously by the use of the cinematograph. With an instrument giving fifty views per second, he was able to follow the process in its details, and to show that it needed but a quarter of a second for the cranium to "explode," and only one-twenty-fifth for fracture of the vault to occur. He could see also that in the first two views, *i.e.*, one-twenty-fifth of a second, the skull was actually lifted above a line traced for the purpose, returning in the third view to its former position This would indicate a violent excentric movement of the cerebrum, or of particles of the cerebrum, and would give proof of what one had considered as theory. Nimier was able to secure series of cinematographs at the rate of 120 views per second. Of these, two are here reproduced. (Figs. 28 and 29.) The shot in each case was fired at five metres range from the Gras rifle. In the second series (I quote from Nimier) it is seen (Fig. 29) that the head has not been exploded. The fragments of the skull are still held in place by the scalp. The first view shows the head before the shot; in the second one can be seen a hail of small particles emerging from the wound of entrance, the bullet being yet inside the cranium; the latter shows very plainly a considerable lifting

Fig. 28.

Fig. 29.

Figs. 28 and 29.—Cinematographic Pictures Showing the Explosive Effects of a Bullet upon a Human Cranium. (Nimier, in Chipault's "État Actuel de la Chirurgie Nerveuse," vol. i., p. 68.)

* "Ueber Schussverletzungen des Gehirns." Archiv f. klin. Chir., 1898, Bd. lxvii., p. 608.

of the vertex. In the third figure the head, which was simply resting on a board, is lifted in its entirety; in addition it shows a projection in the occipital region, which opens widely, and beyond this one can actually see the bullet, which therefore has required no more than $\frac{2}{120}$, or $\frac{1}{60}$, of a second to traverse the skull completely. Finally, in the fourth view there is seen an accentuation of the total displacement of the head, and an enlargement of the wounds both of entrance and of exit.

The first series (Fig. 28) shows the explosion of the head; a detailed description is unnecessary.

The above account of the lesions of skull and brain from modern gunshot wounds, it must be said, is somewhat schematic. The late literature bearing upon the various wars (of the past few years) contains not infrequently accounts of marked exceptions to these types. For instance, Franz (*Archiv f. klin. Chirur.*, Bd. LXXXI., p. 136) reports three cases of recovery from perforating wound of the cranium, one at 300 metres, one at 40 metres, and one even at 20 paces, all unattended by any very extensive destruction of bone or brain. This was in Southwest Africa in the fighting against the Herreros. Other similar cases are not difficult to find, as for instance Kroenlein's second case (*vide infra*). On the other hand, Kroenlein reports a peculiar observation (*Archiv f. klin. Chirur.*, Bd. LIX): A man committed suicide by shooting himself just above the left ear with the Swiss repeating rifle, model 1889, which possesses a muzzle velocity of 600 metres (nearly 2,000 feet). In this case the vault was burst open, and the brain cast out nearly intact. The cerebrum with its two hemispheres was found two feet away from the head, torn off at the medulla, its base badly lacerated, but its convexity almost whole. A yard further off lay the cerebellum, of which, however, only the left hemisphere was well preserved. The track of the bullet could not be found. Shortly afterward a very similar case was reported to Kroenlein by H. Ziegler of Winterthuer, and several others have been found in the literature. (Browne, *Lancet*, Aug. 26th, 1893; Nimier, "Blessûres du Crâne et de l'Encéphale par Coup de Feu," p. 107, Paris, Felix Alcan, 1904.) Kroenlein could venture no explanation of such an occurrence. Hildebrandt, however, on the basis of certain experiments, has put forward the theory that such an *exenteratio cerebri* must be due to the rapid inrush of air into the opening made by the bullet, which is really for the moment a vacuum. If the skull is burst open widely enough and early enough the propulsion imparted to the brain by the bullet, assisted by this forcible inrush of air, may be sufficient to tear the cerebrum loose and fling it intact outside the skull. (See Hildebrandt, *Arch. f. klin. Chir.*, Bd. LXXII., Heft 4; also Bd. LXXIX., p. 573.)

Revolver Wounds.—The wounds from the small firearms of civil life are analogous to those of the army rifle at long range, save with unjacketed, soft-nosed bullets. The missile rarely has force enough to perforate the bone twice, frequently not even once. The fracture it causes is more like a local inbending fracture with some splintering than the clean drill-hole with extensive fissuring of the service rifle, although the large revolvers may cut a fairly large and regular hole. (See Fig. 30.) It shows usually one or two concentric and several short radiating fissures only. When it has force enough to traverse the brain it is very characteristic of it to ricochet back from the opposite side of the cranium, and come to lie in the white substance of the cerebrum.

Prognosis.—The prognosis of these wounds depends primarily upon the velocity of the bullet at the moment of impact and the area of brain wounded;

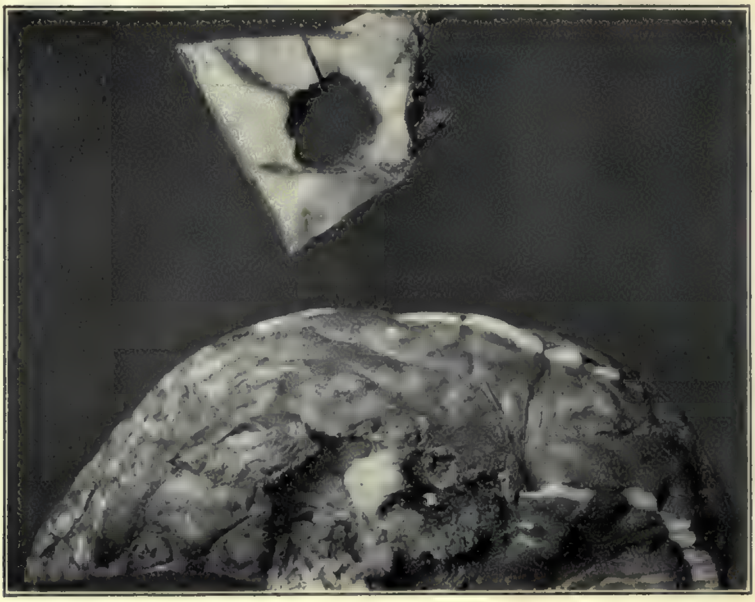


Fig. 30.—Bullet Wound (Revolver), Showing Wound of Entry in Skull and Lesion of Subjacent Temporo-sphenoidal Lobe. (Royal Victoria Hospital, Path. Dep't, 84, '05.)

secondarily upon the early complications of hemorrhage and œdema, and the late one of infection. The greater the velocity, the greater the damage done. If the middle or posterior fossæ be traversed, death is the rule, though exceptions are found in recent literature (Franz); if the frontal lobes alone be involved, recovery may easily occur.

The medical literature arising out of the Russo-Japanese War has in the main merely confirmed our previous knowledge; and this has been excellently summarized in Major Borden's article. The dictum of von Bergmann that infection is very little to be feared from the bullet or its passage through the clothes in cases of clean-cut holes still holds good. The splintered, jagged wounds from shell and shrapnel, which are apt to carry in to the meningeal spaces and the brain large pieces of clothing, skin, and the dirt of the neighboring epidermis, are of much greater danger. As to the immediate mortality, it is as great as ever, if not greater; von Bruns' appellation of "humane" to the modern bullet is unjustifiable in respect of cranial wounds. In the Boer War about seven out of ten were killed on the spot, or died on the field. Of the other three, at least half succumbed later.*

The prognosis of revolver wounds is naturally much more favorable, but varies with the size of the weapon. Not infrequently with the smaller revolvers there is not even unconsciousness; and the danger lies in such complications as compression from hemorrhage, or meningitis. The favorable cases are those in which the frontal lobes alone or chiefly have been injured, as is frequent in the suicidal shot through the temple. The nearer the base and the nearer the medulla the greater the danger; and this, on the one hand, from injury to larger vessels; on the other, from damage to vital centres. Wounding of the ventricles is also very serious, as blood so quickly runs down into the fourth ventricle and kills by rapid compression of the vital centres situated there. In Horsley and Kramer's experiments, the animals that were saved from immediate death by artificial respiration died secondarily of cerebral compression from hemorrhage into the ventricles.

Treatment.—The outstanding fact is the marked tendency shown by surgeons of the Russo-Japanese War to abandon the more or less pronounced non-interference policy of von Bergmann and his school, in favor of early interference. As is well known, von Bergmann strongly advised non-interference and the occlusive aseptic dressing, restricting operation to such cases as developed symptoms of cerebral compression or of infection. Zoege von Manteuffel, Hildebrandt, and van Oettingen, on the contrary, recommended early trephining in all cases in which there is the least suspicion of splintering, with the object primarily of removing all possible sources of infection. The frequency with which these cases are complicated by meningitis and abscess is to them sufficient justification. Naturally such work, to be of value, must be done early, consequently in a field hospital. The question is still under discussion. Conditions in peace are entirely different. Here there can hardly be any question but that all of the more serious cranial wounds should be explored under an anæsthetic, with the prime object, not of removing the bullet, but of cleansing the wound. If, however, the wound of entrance is small and there is no evidence of splintering, it may with reasonable safety be treated with no more than an aseptic dressing. Such will be the case with many of the wounds inflicted by the smaller revolvers and pistols. Where possible, skiagrams should be taken to locate the bullet. Unless the latter be very near the surface and readily accessible, it is certainly best to follow von Bergmann's advice and leave it alone.

* See Hildebrandt: Centralbl. für Chir., 1906, No. 25; also Berl. klin. Woch., 1906, No. 13. —Treutlein: Münch. med. Woch., 1906, No. 25.—Van Oettingen: Münch. med. Woch., 1906, No. 7.—Franz: Arch. f. klin. Chir., Bd. lxxxi., Theil ii., p. 134.—Makins: "Surgical Experiences in the Boer War."

Early trephining may be required on account of the development of serious signs of compression; and a close study of the blood pressure in this connection is of great value. In such a case one would naturally enlarge the wound of entrance with rongeur forceps, remove all accessible blood-clot, and, upon necessity, do the same at the wound of exit. On the other hand, if for instance there were insufficient evidence at these points to account for the degree of compression present, and if a fatal issue were threatening, it would be justifiable to do a purely symptomatic decompression, preferably Cushing's intermuscular operation in the right temporal region, if that were not already the site, as it so frequently is, of the wound of entrance.

Cannon's experiments * upon the development of cerebral œdema as the result of severe concussion showed the danger of compression from mere swelling of the brain inside its rigid case. Such an œdema must occur with still greater certainty in such wounds as those under discussion, and doubtless represents a large factor in the development of compression, perhaps the major factor where hemorrhage is slight or where the blood has an easy escape through the wound of exit or through that of entrance. A decompressive operation would surely be justifiable in such cases to meet the sole indication of dangerous œdema cerebri; and yet, so far as I know, such a procedure has never been definitely proposed.

The question of operation where infection is developing is subject to the same indications as in the case of fractures of other causation. When abscess develops in the cerebral substance it is usually near the surface and of easy access.

If, in the subsequent course, symptoms develop that point to cortical irritation—usually, of course, irritative motor symptoms—the suspicion of a bone splinter pressing upon or penetrating the area of cortex indicated is sufficient to justify trephining for its removal. Symptoms of paralysis, however, afford no such indication; such a condition might easily be due to the cutting of nerve fibres in the path of the bullet, for which trephining could do nothing.

If the patient survive and the bullet remain lodged inside the brain, and give no symptoms, it should be left undisturbed. When, from epilepsy or other complications, it may be necessary to undertake its removal, its position must first be exactly determined by means of special *x*-ray examination. The various instruments for this purpose are so technical that their consideration hardly enters a work of this description.

Hyperalgetic Zones in Cranial Injuries.—The occurrence of definite zones of hyperalgesia in the scalp and neck as the result of gunshot injuries was first accurately recorded by Wilms † of Leipzig in 1903, at the German

* Cannon: "Cerebral Pressure Following Trauma." Amer. Jour. of Physiology, vol. vi., 1901, p. 91.

† Wilms: Mittheilungen a. d. Grenzgebieten d. Med. u. Chir., 1903, xi., 5, and also, Berliner klin. Woch., 1904, No. 17.

Surgical Congress of that year. Since then Milner * and Riebel † have each published a case in point; and finally, Vorschuetz,‡ examining carefully all cases of cranial injury, has found and reported exhaustively twelve instances from Tillmanns' clinic in Cologne. When these cases are analyzed the striking point is found to be that the hyperalgesia in all instances occupies the distribution of the second to the fifth cervical nerves, or some part of their territory; never, or practically never, the trigeminal area. The hyperalgesia is found, therefore, over the vertex, the parietal and occipital regions, and over the neck and shoulders, not over the face. Until Vorschuetz's investigations it was believed that the phenomenon was seen only in cases of gunshot injury, and one of Riebel's conclusions states this categorically. Of Vorschuetz's twelve cases, however, only one concerned a firearm wound; the others were all instances of fracture and even of mere concussion, as clinically diagnosed.

The etiology is still more or less obscure. Undoubtedly the condition is analogous to that of skin hyperæsthesia in certain parts of the trunk which, as long ago as 1892, was shown by MacKenzie,§ and in 1893 independently by Head,|| to be due to visceral disease or inflammation, the pain originating in the sympathetic nerve supply of thoracic or abdominal organs and being reflected out through spinal nerves of the corresponding cord segments by way of communicating branches. The segmental arrangement of the cord, however, which makes this conception clear and comprehensible enough in the region of the trunk and limbs, can in the brain be followed out to but a very limited extent, and the exact girdle arrangement is not clearly seen. Vorschuetz traces the path of the stimulus as follows: The irritation caused by the wound of cerebral substance is transmitted along the radicles of the sympathetic (which, as the carotid plexus, accompanies the vessels even in their terminal branches), as far as the superior cervical ganglion; at which point it is carried along the rami communicantes to the peripheral nerves. Now, the peripheral nerves which are especially connected in this way with the superior sympathetic ganglion are the first four cervical branches. Consequently, referred or reflected pain in the area of distribution of these cervical nerves becomes fairly comprehensible. Further, Vorschuetz demonstrated that, when but one side of the brain was injured, the hyperalgesia was also unilateral; whereas, when both sides were injured, it was bilateral. This is probably the correct explanation. Yet it is a question still under discussion whether the cerebral vessels possess nerve fibres or not; and it has lately been shown that the brain matter itself in the human being is insensitive to pain (Heidenhain, Mitchell, Cushing).

The duration of these hyperalgetic zones may vary greatly. In Wilms'

* Milner: Berliner klin. Woch., 1904, No. 17.

† Riebel: Surgery, Gynæcology, and Obstetrics, December, 1905.

‡ Vorschuetz: Deutsche Zeitschr. f. Chirurgie, May, 1907.

§ MacKenzie: Medical Chronicle, 1892.

|| Head: Brain, 1893–94.

cases it was short; in Vorschuetz's, uniformly long, lasting months—even three years in one case.

The medico-legal importance of the phenomenon is evident. While but few cerebral injuries will show hyperalgetic zones, the contrary holds good, *viz.*, that every hyperalgetic zone means cerebral injury. Many men seek damages for obscure head symptoms of a purely subjective nature resulting from accident; and the medical expert often finds it extremely difficult to form a sure judgment in the matter. It is plain, therefore, of how great value such an objective sign as that of hyperalgetic zones would, if found, be in such cases; and also how little subject to the possibility of simulation.

Apparently there is no effective treatment of the condition. The removal of the bullet in Vorschuetz's case did not seem to influence the severity or the duration of the tenderness. One may only hope, as happened in Wilms' patients, for early spontaneous disappearance.

III. THE BRAIN AND ITS COVERINGS.

Introduction.

To the ordinary medical man, harassed by the multifarious and pressing duties of general practice, and to the student aghast at the amount and variety of knowledge that he is expected to acquire in the fleeting four or five years of his course, the brain, both anatomically and physiologically, is apt to remain more or less of a *terra incognita.* With a difficult anatomy and a difficult physiology to start with, forming a groundwork too often insufficiently laid down, what wonder if the superstructure of pathology and its superstructure again of symptomatology are frequently flimsy? Yet, there are certain outstanding truths in the physiology of cerebral lesions an understanding of which needs no very profound knowledge of cerebral structure nor of cerebral physiology.

In the field of cerebral surgery the dominating factor is compression and its effect on brain tissue. While any other tissue may be compressed with comparative impunity, that of nerve is compressed only at the cost of immediate loss of function, of slow restoration if pressure be relieved, and of atrophy without regeneration if pressure be not relieved. Its high degree of differentiation makes it an easy prey to insignificant trauma, and its injury is frequently attended by early and easily recognized symptoms. Where local pressure or death of a muscle fibre passes unnoticed, that of a nerve fibre gives unmistakable signs, and gives them regularly. In this fact lies the attraction of working out a diagnosis in lesions of the nervous system. The compression of nerve tissue, except in the silent regions of the brain, will produce definite symptoms.

A great many of the lesions which affect the brain, and especially those which have a surgical bearing, do so by reducing the available space inside the skull. The symptoms of hemorrhage, of tumor, of infection, of hydrocephalus, depend in the main upon the compression which these various lesions directly exert upon the brain. Compression, local or general, is the dominant note.

Anatomical Considerations.—THE ARTERIES OF THE BRAIN.—The blood supply to the brain, anatomically considered, is in so far peculiar that the vessels penetrating the cerebral substance from the pia (save those which go direct to the white substance) almost immediately break up into a fine capillary network. As the vessels branch off at right angles there occurs a rapid fall of blood pressure; and this insures a slowing in the capillary stream of the nerve tissue, and by that fact improved nutrition. Moreover, different parts of the brain are differently supplied. The midbrain, the large basal ganglia, and the choroid plexus have each their private and independent supply from the main branches. These are end-arteries, and collateral circulation is rarely observed. On the other hand, the cortex and white substance get their blood supply from vessels lying in the pia. These anastomose freely; but, *ipso facto*, they are liable to transmit infection. The gray matter where nerve cells are most densely aggregated is much better supplied with capillaries than the white.

The principal arteries, the areas which they supply, and their course through the brain ought to be accurately known, inasmuch as, being in certain instances terminal, any unnecessary ligation of their trunks may induce softening. Moreover, their obstruction has, by embolus or thrombus, given rise to definite symptoms which, as a matter of diagnosis, need to be understood. In this work there is hardly space for the necessary detail, and the reader is referred to anatomical text-books.

THE VEINS OF THE BRAIN.—The veins of the brain are thin-walled, distensible, possess a large capacity, and are without valves. The sinuses, on the other hand, are not distensible; neither are they easily compressed save under conditions of general compression. Outflow is abundantly provided for. If the main exits are blocked there exist numerous byways of escape—through the posterior condyloid into the spinal veins, through the emissary veins of the diploë (see Plate XXXI, Fig. 1), and through the orbital veins.

The venous circulation, from the pathological point of view, is in many respects more important than the arterial. The more serious effects of cerebral compression begin and progress to their height from the venous side and are the expression in large part of venous obstruction. This obstruction is also seen with great frequency in the thromboses of various causation affecting both veins and sinuses, a condition which is far more frequent than arterial embolism. As many of the arteries are terminal, so also are certain of the veins; and collateral circulation in each case is difficult if not impossible, so that softening may occur with obstruction of the one as readily as with obstruction of the other. For example, if the veins of Galen, which empty into the sinus rectus, are blocked, draining as they do the choroid plexuses of the ventricles and the adjacent cerebral substance, there will occur usually an internal hydrocephalus as the result of stasis in the radicles, causing even a hemorrhagic exudate into the ventricles. There are also certain trunk veins of the cortex, as Horsley has shown, whose obstruction may be followed by localized cerebral softening.

The veins of the cortical surface of the hemispheres run chiefly from below upward and somewhat backward, and the large majority of them empty into the longitudinal sinus. Luys (see Fig. 31), by careful injections, has shown that in the anterior portion of the longitudinal sinus they empty at an oblique angle from before backward, and therefore with the current; while as one goes backward, and especially from the Rolandic region back to the torcular, their course is obliquely from behind forward, so that they empty into the sinus against the current. The largest of them are those which drain the Rolandic area and empty into the sinus about the Rolandic region. As a matter of fact, the majority of these pass, not into the longitudinal sinus itself, but into the parasinoidal sinuses, or, as the French call them, the "blood lakes," which extend on either side of the sinus proper to the width of one-half to one inch. The danger of operating over the upper portions of the cortex next to the median fissure consists largely in the difficulty of avoiding these blood lakes. The cerebral veins, so far as has been ascertained, do not possess valves and they can be injected, as Luys did, from the sinus, though their oblique entrance renders this not particularly easy.

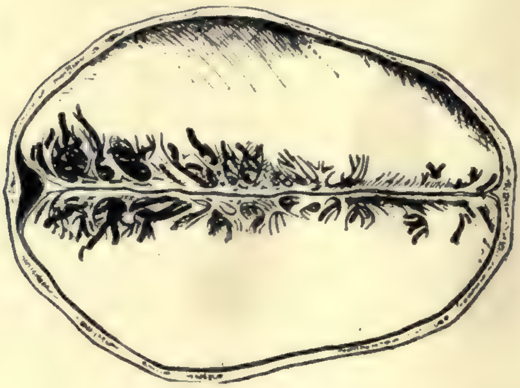


FIG. 31.—Illustration Showing the Entrance of the Cortical Veins into the Longitudinal Sinus. Note the differing direction of their entrance from before backward—with the current anteriorly, and against the current as one goes backward. Note also the width of the "danger zone" which the sinus with its " blood lakes " and cortical veins establishes, a width reckoned by Luys as being at least 2.5 cm. from the middle line on either side. These facts have a practical bearing in cases of trephining over the midline or in cases of ligature of the sinus. (From Luys, Thèse de Paris, 1900.)

The veins of Galen collect the blood from the choroid plexuses of the ventricles and the circumjacent cerebral substance, pass back into the straight sinus, and so into the torcular. The course into the lateral sinus, the sigmoid, and then into the internal jugular is sufficiently indicated in the accompanying plates. (Plate XXXI, Fig. 2; Plate XXXII, Fig. 1; and Plate XXXIV, Figs. 1 and 2.)

The cavernous sinus lies at the side of the sella turcica and communicates with its fellow of the opposite side by the circular sinus surrounding the sella turcica. Each receives the ophthalmic vein from the orbit and is therefore

EXPLANATION OF PLATE XXX.

The Subarachnoidal Spaces in Frontal and Median Sections.

FIG. 1.—Frontal Section of the Meninges (Enlarged) in the Region of the Longitudinal Sinus (*schematic*). *a*, Lateral lacuna; *b*, subdural space; *c*, vein; *d*, bone; *e*, diploic vein; *f*, dura mater; *g*, intradural space; *h*, arachnoid; *i*, subarachnoid space; *j*, pia mater; *k*, cortex cerebri.

Note the intimate anatomical relation of the Pacchionian bodies and the pial veins to the sinus and the lateral lacunæ on the one hand, and to the subarachnoid space on the other, as explanatory of the easy passage of cerebrospinal or other fluid from the arachnoid spaces into the pial veins and the sinus itself. (Kocher, *loc. cit.*, Fig. 4, p. 10. Original from Merkel's Anatomy.)

FIG. 2.—The Subarachnoidal Spaces in Median Section, Left Half Viewed from the Right. (Spalteholz-Barker's "Hand Atlas," 2d ed., vol. iii., p. 682—after Key and Retzius.) The Subarachnoidal spaces and the ventricles of the brain connected with them have been injected with a blue-colored mass. The falx cerebri has been removed. Note the large capacity of the cisternæ at the base, especially those enveloping the cerebellum and medulla.

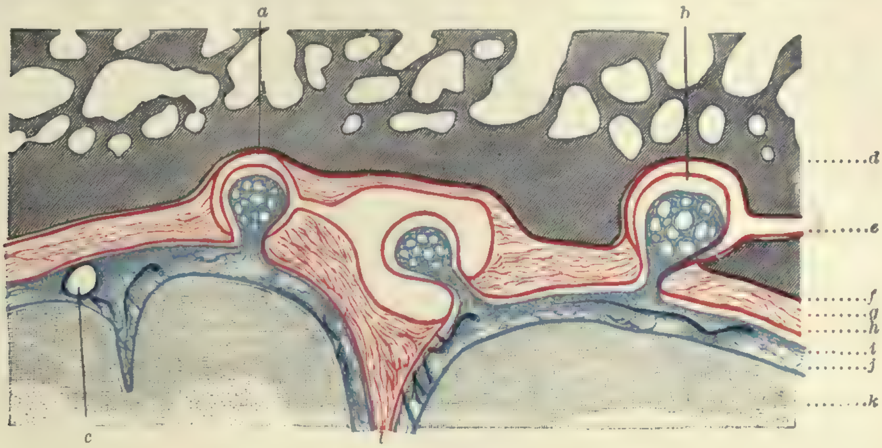


FIG. 1.

a, Lacuna lateralis; *b*, subdural space; *c*, vein; *d*, bone; *e*, diploic vein; *f*, dura mater; *g*, subdural space; *h*, arachnoid; *i*, arachnoid space; *j*, pia mater; *k*, cerebrum; *l*, falx cerebri.

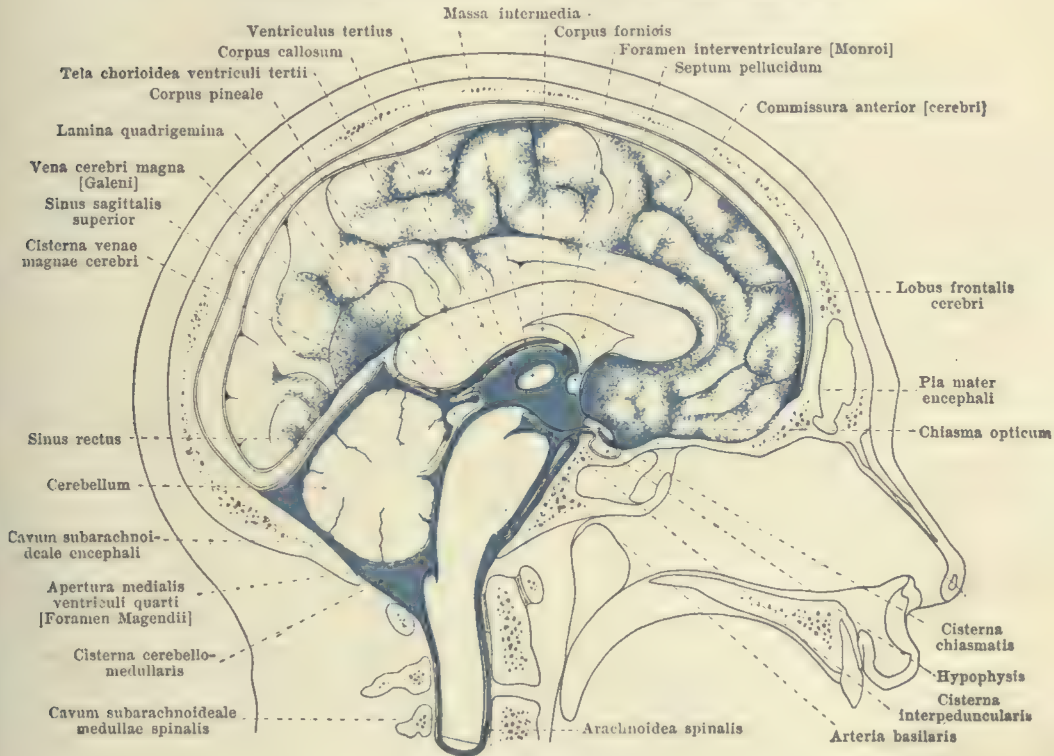


FIG. 2.

MEMBRANES OF THE BRAIN

(From Spalteholz's Handatlas der Anatomie des Menschen, Leipzig, 1903.)

FIG. 1.—Diagrammatic enlarged frontal section of the membranes of the brain in the neighborhood of the sagittal sinus, showing also the lacunæ and the arachnoidal villi. (The dura mater is colored red, and the pia mater blue.) (From Nothnagel's "Path. u. Therapie," after Merkel.)

FIG. 2.—Subarachnoidal spaces as seen in a median section of the head. (The spaces themselves and the cerebral ventricles which communicate with them have been injected with a blue coloring material; the falx cerebri has been removed.)

especially subject to thrombosis as a result of infection spreading backward from the orbit. The liability of the cavernous sinus to rupture from bursting fractures, which so frequently pass through the middle fossa and into the sella turcica, is apparently great. Yet, as a matter of fact, it does not seem, comparatively speaking, to suffer from this injury frequently; at least one would judge so from post-mortem evidence and from the lack of any great number of arterio-venous aneurisms in this situation.

The *cerebro-spinal fluid* is present normally in the cranium in but slight amount; "little more," as Hill remarks, "than the synovial fluid in a joint." Although the subarachnoid space, containing the fluid, is small over the cortex where the brain lies close to the dura, yet at the base it opens out into reservoirs, called cisternæ, which under injection seem to be of large size. These, while not normally containing any large amount of cerebro-spinal fluid, have at least a large capacity. Probably this basal collection of fluid acts as a water-bed and prevents undue forcing of brain against underlying bone, especially in conditions of sudden displacement, as from blows on the head. These basal cisternæ are well shown in the familiar picture of Key and Retzius (Plate XXX, Fig. 2), which was obtained by injections under pressure; the blue injection mass representing far more than the normal amount of cerebro-spinal fluid.

The choroid plexuses are now generally accepted as almost the only source of the fluid. Inasmuch as the vessels of the plexus are extremely numerous, and nerves have been demonstrated in them, and since, as Findlay has shown, they are lined with a stratum of columnar and cubical cells often several layers thick (reminding one somewhat of the kidney glomeruli), the cerebro-spinal fluid should be regarded as a product of active secretion, rather than as a mechanical transudate. Its secretion and absorption probably proceed slowly (Cavazzani, A. and S.) under normal conditions, but certainly under pathological circumstances these changes may take place quite rapidly. Thomson (1899) has reported cases of cerebro-spinal rhinorrhœa in which 500 c.c. flowed from the nose in twenty-four hours.

The fluid is normally under a tension of from 5 to 7 mm. Hg, and this tension about equals that of the cerebral veins. In patients trephined in the cerebellar region, one can often observe this physiological fact in the clinical phenomenon of a protrusion of the soft parts.

The flow of the cerebro-spinal fluid, when collected in the ventricles, is outward through the foramina of Munroe, of Magendie, and of Luschka, and through other small passages, into the various cisternæ and the general subarachnoid space as well of the spinal canal as of the brain. From here it enters directly the meningeal veins, but most freely through the Pacchionian bodies, and so into the sinuses and the diploic veins. (See Plate XXX, Fig. 1.) In this manner it completes its cycle and returns to the vascular circulation.

This direct passage of the cerebro-spinal fluid into the veins, remarkable as it seems, is one of the best-established facts in the physiology of the cerebral circulation, and one of the most important in the question of brain compression. It takes place so easily, as Leonard Hill remarks, that the fluid never can come under a pressure higher than that which exists in the large cerebral veins themselves, so long as no block occurs, such as an obstruction of the ventricular foramina or of the channels connecting the subarachnoid spaces, or so long as the venous blood itself can leave the skull without hindrance.

The cerebro-spinal fluid, as we know from the researches of Haliburton, Mott, Findlay, and others, is not at all the same thing as the lymph of other organs. It is only, indeed, under conditions of venous obstruction that the fluid leaves the skull by the lymphatics at all, and then only slowly and in comparatively small amount. It is, really, a sort of stop-gap. Where spaces arise through dislocation, or retraction, or destruction of brain substance, the fluid immediately fills them. On the other hand, in conditions under which the available cranial space is reduced, especially when this happens with suddenness, it is probably the cerebro-spinal fluid that affords compensation, both by its quick and easy distribution over a large space and by its freedom of escape into the cerebral veins and sinuses, as also into the spinal canal. The fluid, moreover, regulates the respiratory variations in volume of the brain, in so far as these depend upon variations in the distention of the veins. In short, the cerebro-spinal fluid under normal conditions is a ready servant, present when needed, absent when of no service.

As already mentioned, the principal avenue of absorption of cerebro-spinal fluid and of its exit from the skull is undoubtedly by direct passage into the cerebral veins, and more especially by way of the Pacchionian bodies. This was first demonstrated by Key and Retzius. If the reader will remember the anatomical structure of these Pacchionian bodies—consisting of villous outgrowths of the vascular pia into the connective-tissue bundles of the dura and frequently pushing completely into a venous sinus or into the venous lacunæ communicating with the longitudinal sinus—he will more easily understand how this may occur (*vide* Plate XXX, Fig. 1). In Quincke's injections of cinnabar powder into the subarachnoid space the Pacchionian bodies were always found densely colored with the powder; and this as well when the injection was made from the spinal canal as when it was introduced into the skull. The great rapidity with which liquid injected into the subarachnoid space disappears through these bodies into the general blood current was demonstrated originally by Magendie, and later in a very striking fashion by Duret (1878), who, in two hours, saw over half a litre (more than one pint) absorbed from the subarachnoid space.

This question, that of the absorption of the cerebro-spinal fluid from the cranial cavity, is of such importance that I shall quote one or two of Leonard Hill's experiments which may set the matter more graphically before the re der. Hill found that saline fluid injected into the cranio-vertebral canal at any pressure above that present in the cerebral veins disappeared from the cranio-vertebral cavity; the higher the pressure the more rapid its disappearance. By injecting this fluid colored with methyl blue he could trace it passing straight into the venous sinuses, and in so short a time as ten to twenty minutes he found the blue color secreted in the stomach and the bladder. Since the lymphatics in the neck were not even tinged in so short a time, a clear demonstration of the fact is shown that the rapid absorption of fluid from the cranio-vertebral cavity takes place by means of the veins and not by the lymphatics. Cushing found that gas, and particles of mercury even, passed easily by this route into the circulation, as he was able to prove by direct observation of the exposed jugular vein. The importance of this fact in conditions of compression will be discussed later.

The *lymphatics* in the brain are demonstrable with certainty only in the pia, not in the brain substance. They receive the lymph from the perivascular spaces of the brain tissue, collect it in larger lacunæ on the brain surface, leave the skull by the carotid canal, the jugular foramen, and with the vertebral arteries, and so drain into the deep cervical lymph nodes.

Physiological Considerations.—It seems to be a fact of prime importance, established by the work of Althann over thirty years ago, that the effect upon the brain of space diminution in the skull cavity is identical with that obtained by any other process which hinders the cranial circulation, such as, for instance, the ligature of the important arteries of the brain. In other words, the symptoms of compression correspond with those of cerebral anæmia. Leaving aside for the moment the evidence accumulated in favor of this view, we can see at least the extreme importance of the question of the cerebral circulation, and in this sense we shall consider, first, the normal physiology of the cerebral circulation, and, later, its behavior under the pathological conditions of compression.

Cerebral Circulation.—Circulation through the brain is of a somewhat peculiar nature; and the one thing that makes it so is the unyielding box of bone in which the brain is enclosed—a box as little capable of expansion, to quote von Bergmann, as of sinking in. The contents of the cranial box consist of brain matter with its coverings, the blood-vessels and their stroma, the blood, and the cerebro-spinal fluid. A fact to be remembered is that, as before stated, the brain matter is itself incompressible, practically as much so as is water; therefore, the cranium being unyielding and the brain incompressible, room inside the skull is gained only by a displacement of the other constituents. It is not possible for a vacuum to occur inside the cranium, because the veins are capable of undergoing a great variation in compensatory capacity;

and where this compensation does not suffice, any free space that arises is immediately filled by the cerebro-spinal fluid.

From physiological experiment we know that the pulsations of the brain, in the closed skull, depend upon two factors, the cardiac and the respiratory. With each systole and diastole of the heart, and again with every inspiration and expiration, the volume of the blood in the cranial cavity changes.

Inasmuch, then, as the brain is constantly varying in size, even though slightly, from variations in the blood content, it is important to note by what means the changes in space are compensated for.

Now there are certain regulatory mechanisms which control or compensate not only for the normal variations in the size of the brain, but also for the numerous interferences, especially that of an intracranial space-diminution, which may tend to derange in a pathological manner the normal course of the cerebral circulation. There may occur, for instance, an increase in the amount of the arterial blood on the one hand, or of venous blood on the other, within the cranium; and the mode of compensation is different in each. Of these regulatory mechanisms the chief are the cerebro-spinal fluid and the general circulation. The former gives way, and so makes room; the latter influences the amount of blood and the force with which it is driven through the brain. To explain all the experimental work done to elucidate in this regard the rôle of the cerebro-spinal fluid would occupy too much space. Suffice it to say that it recedes from the cranial box by one or all of three channels—the spinal canal, the deep lymphatics of the neck, and the cerebral veins. While we may accept as a fact a certain ebb and flow (under normal conditions) of the cerebro-spinal fluid from the cranial into the spinal cavity, with each respiratory and cardiac variation in the brain volume (as seen *in vivo* by von Bergmann), it is certain that the accommodation thus provided is slight. The same is true to a greater extent of the second avenue of escape, that by the cranial nerve sheaths into the deep cervical lymphatics. The main escape, as has been pointed out above, is directly into the cerebral veins and the longitudinal sinus, especially through the Pacchionian bodies.

Doubtless, however, the more important of these regulatory mechanisms is found in the general circulation of the rest of the body. Along this line very numerous experiments have been performed with the object of influencing the general circulation in order to see what effect the resulting change would have upon the cerebral blood-flow. Thus Roy and Sherrington tested the effect of the excitation of sensory nerves, of asphyxia, of anæsthetics, and of various drugs such as morphia, curare, and amyl nitrite. They registered the variations in brain volume by an ingenious pressure-gauge applied directly upon the cortex, after taking care to allow the cerebro-spinal fluid to flow off in order to exclude any possible influence it might have. In this way expansion of the brain would correspond to a dilatation of its vessels, and contraction to a narrowing. They

EXPLANATION OF PLATE XXXI.

Venous Channels of the Skull and Dura Mater.

FIG. 1.—The Vena Diploica Viewed from the Right. (The lamina externa of roof of skull has been filed off.) (Spalteholz.)

Note how large these veins are; and how free the collateral circulation may become through the emissaries in conditions of high intracranial tension when the normal escape of blood by the jugular veins is cut off. The very free hemorrhage from the bone often met with during operation under such circumstances is thus explained.

FIG. 2.—Sinuses of the Dura Mater of the Right Half of the Skull Viewed from the Left. (Spalteholz.)

The illustration serves to make clear the situation and course of the sinuses with reference to their injury or inflammation.

Note the communication of the occipital sinus with the spinal plexus (plexus venosi vertebrales interni) which affords a collateral circulation in conditions of intracranial venous stasis.

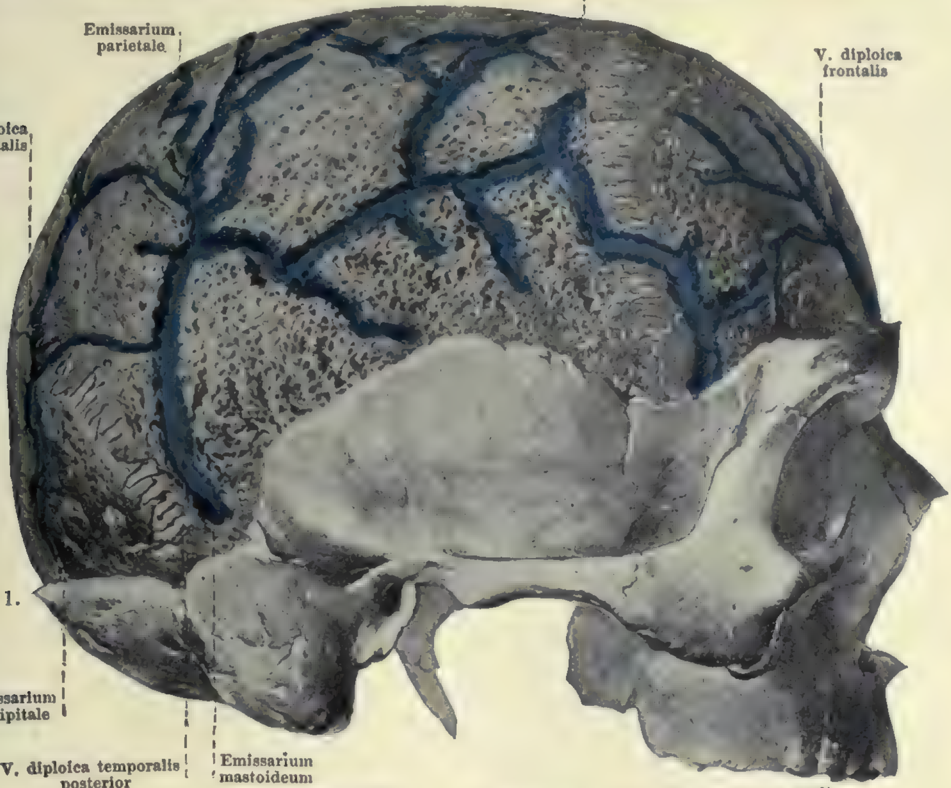


FIG. 1.

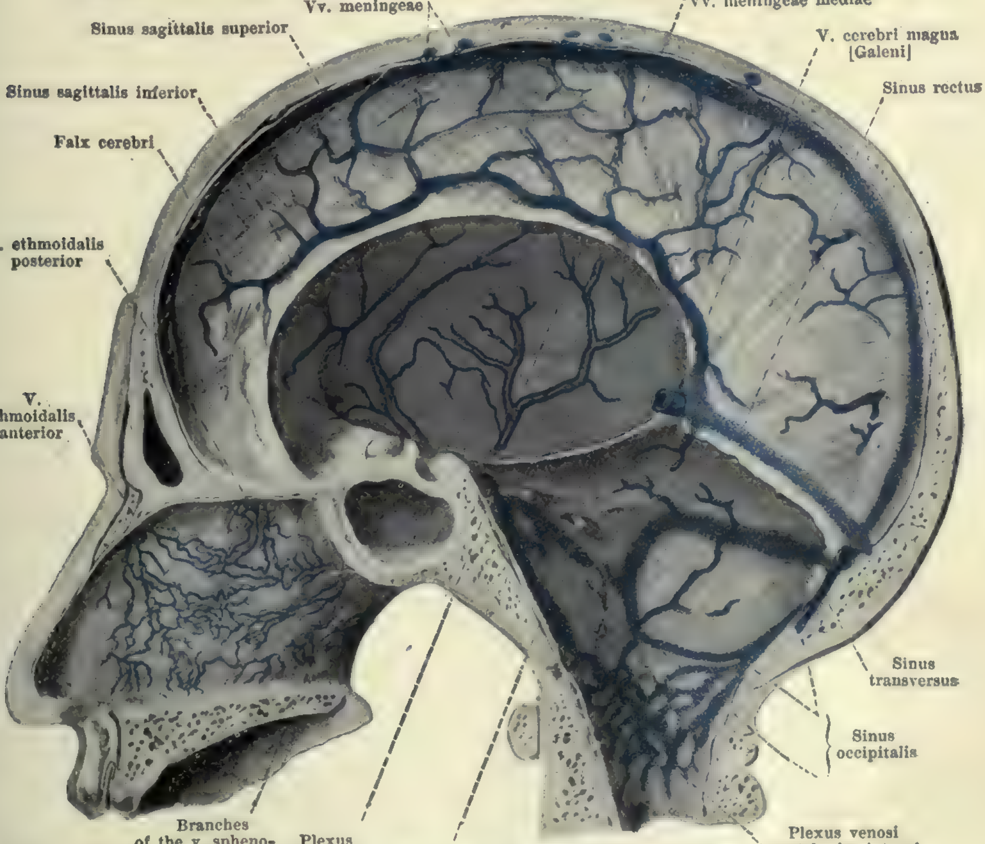


FIG. 2.

VENOUS CHANNELS OF THE SKULL AND DURA MATER. (Spalteholz.)

found in a general way that the cerebral circulation *passively* followed the changes in the general circulation. Stimulation of the sensory nerve by its pressor effect on arterial pressure gave expansion; cutting off the splanchnic nerves, by means of the consequent enormous dilatation of the abdominal vessels, caused contraction of the brain mass. And so with other experiments, the cerebral circulation seemed to follow *passively* every change in the general circulation, from whatever cause it might arise. The exhaustive investigations of Leonard Hill, and later of Cushing, have amply confirmed this fact.

Geigel * has introduced certain rather convenient terms to describe the varying conditions of the brain's circulation. In his definition ordinary cerebral circulation may be denominated "eudiaemorrhysis"; an increased rate of blood-flow through the brain is "hyperdiaemorrhysis"; while slowing or cessation of blood flow is called "adiaemorrhysis." Kocher has substituted for this last term the better one of "dysdiaemorrhysis," indicating difficulty in the circulation. In conditions where the arterial pressure is increased, that is, where one may consider a certain hyperæmia of the brain to exist, it has been demonstrated by various experiments that the rate of blood-flow through the brain is by no means diminished, but rather definitely increased; and this holds good even when blood pressure is carried to a considerable height experimentally. Thus there is in this sense no such thing as an injurious hyperæmia.

As has been mentioned, any increase of intravascular pressure from the arterial side increases cerebral circulation from eudiaemorrhysis to hyperdiaemorrhysis, and is therefore of value to brain nutrition and function. Nor can the increase of arterial flow do any damage in the way of occupying too much space and causing compression, for the reason that, in the first place, the veins will allow a considerable degree of compression before obstruction is reached; in the second place, the cerebro-spinal fluid, whenever pressure rises, flows off with the greatest ease into the veins, in a slight degree also into the lymphatics, thus allowing extra room; while in the third place, the muscular walls of the arteries themselves will permit only a certain degree of transmission of the intravascular pressure to the extravascular brain.

When we come, however, to consider difficulty of circulation from the venous side the matter is very different. Because of the normal escape of cerebro-spinal fluid by the veins any obstruction to venous outflow must cause, as shown by the work of Ziegler, Hill, and Elder, a rise in the pressure under which the fluid stands. Now, the exit of venous blood from the skull is chiefly by the jugulars; but there exist, as shown so well in Cushing's injection experiments, numerous side-exits, such as the emissaries through the diploë (Plate XXXI, Fig. 1), the ophthalmic leading into the orbital and face veins (Plate XXXIV, Fig. 2), the vena condyloidea into the deep neck veins, and the occipital sinus anastomosing with the spinal plexus (Plate XXXI, Fig. 2). These safety exits are all abun-

* Geigel: "Die Mechanik der Blutversorgung des Gehirns," Stuttgart, 1870.

dantly utilized when the main one is blocked. Thus the bleeding from scalp and skull may be extremely troublesome in operations under high compression, as every surgeon knows. So long, however, as these exits are open, venous stagnation cannot cause manifest brain compression. Thus, clinically, the extreme venous stagnation, due to extracranial causes, such as retro-sternal goître and thoracic tumors, can cause at the most only symptoms of latent brain compression, dizziness, headache, ringing in the ears, insomnia, slight disturbances of vision, and so on. If, on the other hand, an obstruction to venous outflow progress intracranially as far as the capillaries, then every side-path is gradually cut off, and the symptoms of manifest compression may appear. This result is further assisted by the fact, so well proven by the observations of Leonard Hill, and later by Cushing, that, with a certain degree of space diminution, the medulla and cerebellum are forced down into and upon the foramen magnum, thus cutting off the escape of cerebro-spinal fluid into the spinal canal and adding to intracranial tension.

Hydrostatics and Hydrodynamics of the Cerebral Circulation.—It has been said that the general circulation furnishes the chief means of compensation for changes in the cerebral circulation, and I have referred to certain factors investigated by Roy and Sherrington which influence especially the former, such as the excitation of sensory nerves, asphyxia, anæsthetics, various drugs. One other factor, however, is of such importance that it demands a paragraph to itself. I refer to the influence of gravity, a subject which has been worked out especially by Grashey* and later by Leonard Hill.†

It may be premised that the normal forces controlling the circulation are of two kinds, *hydrostatic* and *hydrodynamic*. As Hill puts it, the hydrostatic moment expresses the simple passive change produced by the hydrostatic effect of gravity; the dynamic moment expresses the effect of the cardiac, vasomotor, and respiratory mechanisms. As will be shown, the latter compensate for the former. The first is a purely physical effect, the second a vital phenomenon.

The scientific aspect of the effect of gravity is of great practical importance. Indeed, Hill was led to investigate it by observing in a trephined patient that cerebral pressure was negative at the vertex with the patient erect, but positive when he was in the horizontal position; and that it rose as a result of forced respiratory movements. I have had occasion to confirm in a general way these observations in a patient in whom the greater part of the frontal bone was removed for syphilitic necrosis. In this case not only could one see the effect of gravity but also that of any rise in the general circulation caused by the emotions, such as anger.

Hill, in animal work, established first the normal effect of gravity by means of an ingenious instrument devised by himself which he calls his "cerebral

* Grashey: "Festschrift für L. A. Buchner," München, 1892.

† Leonard Hill: "The Physiology and Pathology of the Cerebral Circulation," London, 1876.

pressure gauge." He found that with the animal in the vertical position, feet down, there was an immediate fall in cerebral pressure—that is, the tension under which the cerebro-spinal fluid stands. In the contrary position, feet up, there was an immediate rise. The horizontal position brought about a return to the normal. The general arterial pressure, taken in the femoral artery, gave exactly contrary results. These facts showed that compensation for the normal effect of gravity resided chiefly in the action of the vasomotor centre upon blood pressure; and he proved that the effect was gained mainly by its action on the splanchnic territory, either in the way of constriction or in that of dilatation. This vasomotor compensating mechanism was most evident in erect animals, such as the monkey, and would presumably be still more marked in man.

The second subsidiary compensation of hydrodynamic nature is afforded by the action of the respiratory centre. In the feet-down position respiration was inhibited and was thoracic in type, with the abdomen drawn in, thus supporting the splanchnic veins. In the feet-up position it was hastened and the breathing became diaphragmatic while the abdomen underwent distention, allowing blood to fill the splanchnic veins. A third manner of compensatory mechanism was found in the effect on the vagus centre, by which, in the feet-up position, the heart-beats were slowed, and in the contrary position were hastened. This being true of the cerebro-spinal fluid pressure, Hill proved that it held good also for the pressure in the cerebral veins. With a cannula in the torcular the pressure in the feet-down position sank from over one hundred millimetres of magnesium-sulphate solution to below zero, and blood ceased to flow. Compensation being lacking, the cerebral circulation stood still.

Now, under normal conditions this compensatory mechanism, the chief factor of which lies in the action of the vasomotor centre, is quite effectual; but it is clear that, if anything should happen to disturb the compensating action of the vasomotor centre, the influence of gravity would become extremely serious. Hill proceeded, therefore, to demonstrate the injurious effect of such agencies as interfere with the work of the vasomotor centre. Thus, he found that with destruction of the cord from the seventh cervical to the third dorsal, or cutting of the splanchnic nerves, or chloroform in excess, or curare, or amyl nitrite, or, in general, shock, the general blood-pressure in the carotid would, if the animal were put in the feet-down position, sink to zero and the cerebral circulation would cease; while, if it were put in the feet-up position, no ill consequences would ensue. Parenthetically, it is important for us to notice here the influence of chloroform as an anæsthetic.

With regard to treatment, Hill found that under such conditions artificial aid supplied by pressure on the abdomen (by which, according to Roy and Adami, the quantity of blood flowing out of the heart can be increased by more than twenty-five per cent), or by irritation of the splanchnic nerves, or of the distal cord after section, or by asphyxia, or by adrenalin, in short, all agencies that stimulate arterial pressure, would suffice, if the condition were not too advanced, to restore the blood pressure. In order not to overload the heart too suddenly, Hill advised alternate compression of the abdomen and thorax, rather than continued compression of the abdomen alone. Experiments such as these are confirmative of clinical observations which, in a general way, every operating surgeon has frequent occasion to make.

From the above facts, Hill concludes: "it is manifest that, with the skull intact and compensation for the hydrostatic effect incomplete, the circulation stagnates in the brain in the feet-down posture; and with the skull opened, if the cerebral capillary blood pressure falls below that of a column of blood reaching from the heart to the brain, the capillaries will empty and the brain collapse." Regnard and Salathé observed rapid death in animals that were trephined and kept in the vertical feet-down posture. These experiments, as well as those of Grashey, demonstrate that trephining in the upright position can very greatly influence the cerebral circulation by emptying the vessels through atmospheric pressure.

The practical bearing which these facts have upon shock and upon the surgery of cerebral lesions will be discussed as occasion arises. Here it may suffice to point out in a general way that according to the strength of the vasomotor centre chiefly—at any given moment, say, of surgical intervention—so will our judgment be as to the advisability of elevating the head or the contrary. One position may materially assist the vasomotor centre, the other may complete its overthrow.

At the risk of repetition, one must remind the reader that the most striking result in these experiments lay in the demonstration of the protecting influence of the vasomotor centre. To quote from Hill: "An anæmia of the central nervous system excites the vasomotor centre; if the splanchnic vessels constrict, the blood pressure rises and more blood is driven through the brain. We have in the vasomotor centre a protective mechanism by which blood can be drawn at need from the abdomen and supplied to the brain." Roy and Sherrington * in 1890 had already come to a similar conclusion. Neither of these observers, however, seemed to appreciate, or at least to discuss, the intimate bearing of this general fact upon the phenomena of cerebral compression. The elucidation of this aspect of the subject, together with the complete proof of the existence of cerebral anæmia in compression, *de visu*, was accomplished first by von Schultèn, and later, more completely and more certainly, by Harvey Cushing. Of this, more in the next section.

* Roy and Sherrington: Jour. of Physiology, London, vol. xi., 1890, p. 85.

EXPLANATION OF PLATE XXXII.

FIG. I.—Reproduction from Poirier's "Topographie Cranio-Cérébrale," to show the relations of the lateral sinus to the skull surface, and of the cerebral convolutions to the sutures.

L.O., Left orbit.

S.L., Lateral sinus.

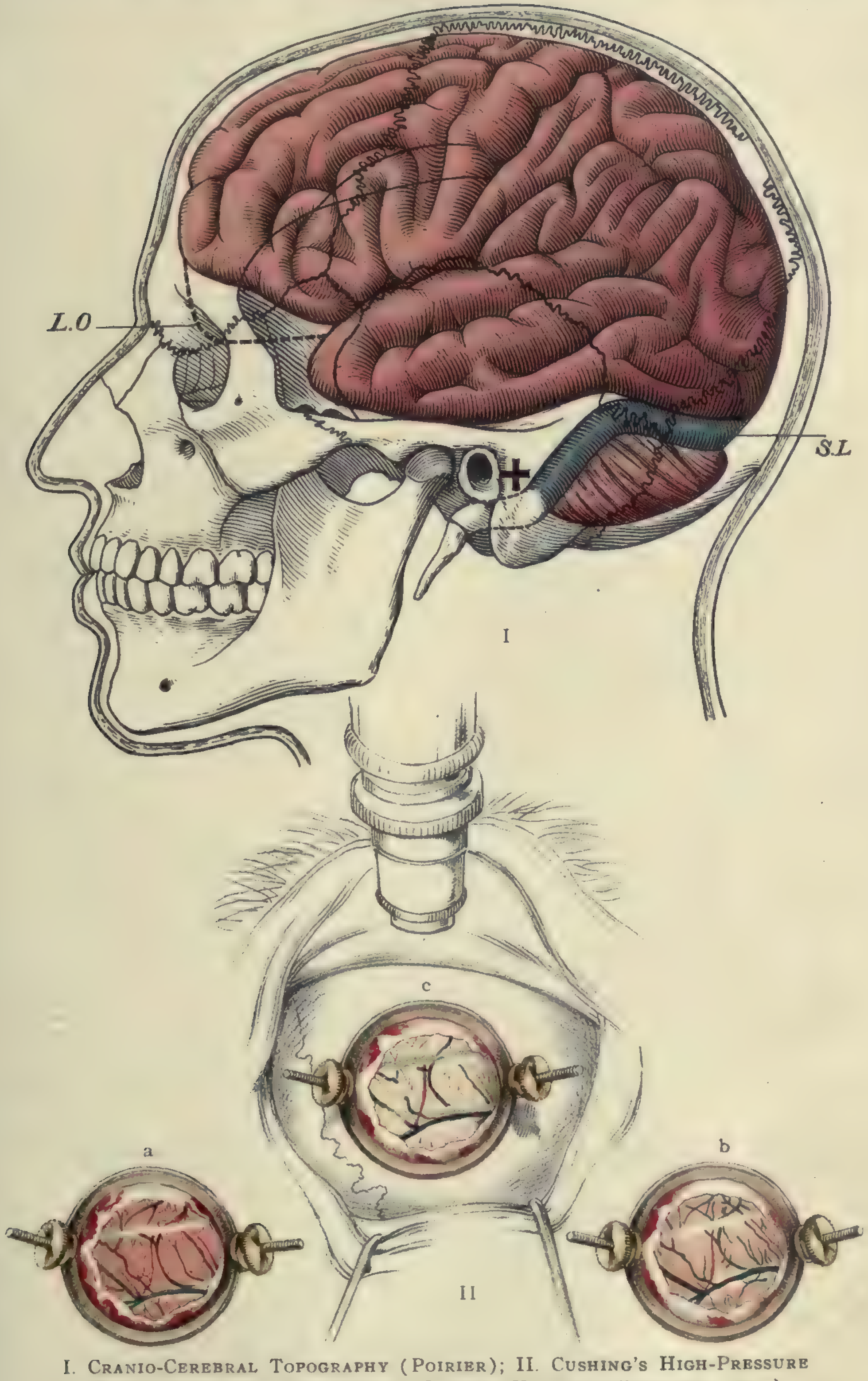
The lateral sinus, running in the level of attachment of the tentorium cerebelli, forms the upper boundary of the cerebellar space, and is therefore a landmark for operations in this region. Note that as it runs into the sigmoid sinus it underlies the middle third of the mastoid process, if one divide the latter into three vertical portions.

FIG. II.—Illustrations Drawn by Harvey Cushing during the Course of Experiments. (Kocher, "Hirnerschütterung, Hirndruck," etc. Nothnagel, ix., 3, 2.)

(*a*) This shows practically normal conditions as seen through a window inserted in a trephine opening. One sees the bone edge, inside which comes a narrow border of dura mater somewhat blood-stained. The capillaries stand out clearly as fine red lines, somewhat more so than normally. In the lower part of the opening a large sulcus vein with two tributaries, showing blue, from which the arteries of smaller calibre are easily distinguished.

(*b*) This illustrates the stage of beginning compression. The veins are fuller and stand out more prominently than in (*a*). The pale-bluish appearance of the cerebral substance itself as compared with the normal pinkish color is noteworthy.

(*c*) The acme stage of compression, in which there is present a severe grade of anæmia of the cerebral substance which shows almost white. The larger sulcus vein is still prominent, and full of partly stagnated blood; the smaller veins are only filled in parts, the intervening stretches being collapsed and showing only a pale vein wall. The arteries are clearly narrower than in previous figures.



I. CRANIO-CEREBRAL TOPOGRAPHY (POIRIER); II. CUSHING'S HIGH-PRESSURE EXPERIMENTS UPON THE BRAIN (KOCHER: HIRNERSCHÜTTERUNG, ETC.)

GEO H WALKER & CO. BOSTON

IV. COMPRESSION OF THE BRAIN.

Although as far back as Hippocrates, and probably even before him, the general symptoms of cerebral compression were fairly well known, it was not till the beginning of the eighteenth century that its pathology and the correlation of pathological with clinical phenomena began to be understood. Galen, for instance (I quote from Leonard Hill), noticed paralysis of movement and sensation following the careless introduction of a guard in the operation of trepanning; and he recognized that the prognosis could be based more or less on the implication of respiration. But Verduc (1712) and Boerhaave were the first to demonstrate that the severe symptoms observed in connection with fluid effusion into the cranial cavity, or with depressed fractures, were dependent upon compression of the brain mass. Boerhaave's observation of that original beggar in Paris who, in "passing the hat," used therefor a piece of his own skull, his brain being covered only by the dura mater, is famous. "And he would frequently permit experiments to be made for a small trifle of money. Upon gently pressing the dura mater with one's finger, he suddenly perceived, as it were, a thousand sparks before his eyes; and, upon pressing a little more forcibly, his eyes lost all their sight; by pressing the hand still stronger on the dura mater he fell down in a deep sleep, which was attended with all the symptoms of a slight apoplexy, merely by this pressure with the hand, which was no sooner removed than he as gradually recovered from the symptoms as they were brought on, the apoplectic symptoms first vanishing, then the lethargy, and lastly the blindness, all his senses recovering their former perfection." (Leonard Hill.)

Somewhat later, about the middle of the eighteenth century, the great von Haller began the study of the symptoms of cerebral compression upon the basis of animal experimentation. His results were simply that upon moderate brain compression dogs suffered pain; upon stronger compression, they fell asleep and snored. Astley Cooper, in 1837, pressing with the finger upon the dura through a trephine hole in the dog's skull, caused first pain and irritative symptoms, then slowing of the pulse and coma. Flourens, in 1831, showed that convulsions represented one effect of compression. Piercing the transparent skull of young pigeons, he caused meningeal hemorrhage, and, upon this, convulsions. These were relieved upon opening the skull and removing the clot. Magendie was the first, in 1837, to demonstrate fully the existence of cerebro-spinal fluid. Before him even the great ones, such as Littré (1707), von Haller, and even Burdach (1822), conceived of the ventricles as being filled with a "vapor." Magendie, with the acquisition of this knowledge, demonstrated the effect of brain compression in a new way. By pressure upon the sac of a spina bifida in a child, he caused bulging of the fontanelles and coincidently somnolence.

There are very many other interesting historical details that one comes across in the older literature, which lack of space forbids our recounting. But our modern scientific knowledge of the subject dates from the well-known work of Leyden (1866), who was the first to study the question thoroughly from the experimental side.

Experimental Investigations.*—In the following pages I desire first to furnish a résumé of our scientific knowledge anent brain compression, *i.e.*, the knowledge gained by accurate experimentation producing known conditions; and only later to correlate the facts of clinical observations with experimental knowledge.

But first it may be well, even if hardly necessary, to remind the reader of the essential physiological facts necessary to the comprehension of the experimental work. Our life, taking the word in its lowest sense, is absolutely dependent on the functioning of the three vital centres situated in the floor of the fourth ventricle—the vasomotor, the vagus or cardio-inhibitory, and the respiratory centres. The vasomotor centre is constantly sending out influences which give tone to the vessels of the body. Its stimulation results in constriction, its depression in dilatation. It is in control of blood pressure through its effect on the arteries. The vagus being stimulated slows the heart-beat and lowers slightly blood pressure. It is the chief agent in the regulation of the rate of the heart. The respiratory centre, like other centres, acts reflexly under the constant inflow of impulses received by its sensory nerves, but it is further affected by the quality of the blood passing through it. The lowering of tension of oxygen in the blood, the augmentation of that of CO_2, increases its excitability, and the movements of respiration are augmented. This is plainly a protective mechanism.

Now, although I desire in these pages to give as prominent a place as possible to the physiological basis of cerebral compression, and although it would be interesting historically to follow the gradual development of our knowledge of this subject, it is impossible in a work of this scope to review in detail the numerous investigations upon the question. One may merely mention, among others, the names of Leyden, Althann, Falkenheim and Naunyn, Duret, Manz, Pagenstecher, Bastgen, Couty, Markwald, von Bergmann and Cramer, Naunyn and Schreiber, Horsley and Spencer, Elder, François Franck, Ziegler, Adamkiewicz, Roncali, Albert, Leonard Hill, Kocher, and Harvey Cushing. I shall therefore do no more than pick out certain landmarks in the history of this

* REFERENCES:—Leyden: Virchow's Archiv, 1866, Bd. xxxvii., p. 519.—von Bergmann: "Die Lehre von den Kopfverletzungen." "Deutsche Chirurgie," Lief. 30.—Also in the "Handbuch der praktischen Chirurgie," v. Bergmann, v. Bruns, and v. Mikulicz, vol. i.—von Schultèn: Archiv f. klin. Chir., Bd. xxxii.—Leonard Hill: *Loc. cit.*—Kocher: "Hirnerschütterung, Hirndruck," etc. Nothnagel's "Spec. Path. u. Ther.," Bd. ix., Th. iii., Abth. ii.—Porter and Storey: Amer. Jour. of Physiol., March, 1907.—The other references, together with many not here mentioned, may be found in the books of von Bergmann, Leonard Hill, and Kocher, the first two of which include particularly good bibliographies. The last represents the most complete work upon the subject that we possess.

development, refer to them briefly, and then proceed to enter with some detail into the finished work as presented by Kocher in his classical monograph, and especially into the work of Harvey Cushing, which was done at first under Kocher's direction at Berne in Kronecker's laboratory, and later was continued independently, chiefly along clinical lines.

These landmarks are Leyden's path-breaking work in 1866, von Bergmann's résumé of the subject in 1880, von Schultèn's investigations in 1885, Leonard Hill's from 1892 to 1896, and finally, Kocher's and Cushing's in 1900. Leyden's work is important because it first established on a scientific basis an understanding of the symptoms of compression; later work has merely enlarged this knowledge.

Leyden's method, frequently used since, consisted in injecting an albuminous fluid into the subarachnoid space. As fluids pass to all parts, are incompressible, and transmit pressure equally in all directions, it is evident that such a method must effect a fairly even compression of the whole brain. It is the method of general as opposed to local compression, and may be compared with such clinical conditions as hydrocephalus, serous meningitis, etc. Parenthetically, it will be well to remark that while the effects of local compression may vary with the locality compressed, and while compression over the bulb is as essentially a local pressure as if it were over the motor region, still it is customary to speak of general compression as affecting chiefly and ultimately the bulbar centres, whether with or without signs of local compression elsewhere, and to think of local compression as belonging to such parts of the brain as give characteristic "local" signs—such as the motor region or the various speech regions.

Leyden, then, injecting fluid under a pressure measured in millimetres of Hg. discovered a more or less regular sequence of compression phenomena. The first symptom to appear at the fluid pressure of 50 mm. of Hg was pain, with restlessness, ascribed to irritation of the dura. Convulsions occurred at 120 mm. and unconsciousness at 130 mm. Dilatation of the pupils was usually a late symptom. Slowing of the pulse was sometimes noted at a pressure of 50 mm., was constantly present at 75, and the slowness increased up to 150 mm. Above this, the pulse became irregular. At 250 mm. it became rapid, more or less suddenly. That the slowing was due to stimulation of the vagus Leyden proved by cutting the vagi, upon which the pulse remained unaffected. Respiration was at first rapid and irregular; in coma it was deep and slow, but, with a high grade of compression, became very irregular, and finally ceased altogether. The heart continued beating two minutes after the cessation of respiration. Such observations revealed in a striking manner the cardinal facts of the working of cerebral compression on the vital centres in the medulla, and the mode of death.

von Bergmann's conception of the manner in which compression acts may be briefly recapitulated:—

First, the general effect of space diminution is a rise in intracranial tension; that is, in the pressure under which the cerebro-spinal fluid stands. This results from the slowing of the circulation in the brain and its membranes. By the laws of hydrostatics such pressure, being transmitted by a fluid, must be generalized. As soon as the fluid pressure surpasses, even by a little, the pressure in the capillaries, the latter must be compressed; and no matter to how slight a degree this compression may act, its effects must be enormous, inasmuch as a very slight narrowing, say by one-tenth, will allow the passage of only half the former stream (Poiseuille's law). That the increase in intracranial tension is caused by an increase in the pressure under which the cerebro-spinal fluid stands is proved by a number of facts: (i) The old clinical observation, made by Magendie and repeated by von Bergmann, that symptoms of cerebral compression may be produced by compressing the sac of a spina bifida or a meningocele. (ii) The results obtained by direct measurements taken in conditions in which there is present cerebral venous stagnation of high grade, such as is artificially caused by compression of the neck veins. (iii) The relief of compression symptoms in dogs when the atlanto-occipital ligament is divided and cerebro-spinal fluid is evacuated. And finally (iv) the evidence furnished by the celebrated case of Hilton. This concerned a patient who, with fracture of the base, had continuous escape of cerebro-spinal fluid from one ear. When Hilton made the patient breathe deeply, then close the mouth and nose with forcible outbreathing, the cerebro-spinal fluid regularly streamed out of the ear, so that in a few minutes over half an ounce was obtained.

Cramer's experiments, in association with von Bergmann, further proved the compression of the capillaries. Taking the pressure in the jugular vein, he found that there was a constant and great fall in conditions of cerebral compression. von Bergmann could construe this only as a lack in the *vis a tergo;* consequently the fall in the venous pressure under brain compression was the result of the compression of the cerebral capillaries caused by the increased tension in the cerebro-spinal fluid.

Now, the tracings of brain compression, as studied experimentally by Leyden in 1866, Pagenstecher in 1871, Duret in 1874–78, and himself 1876–80, were strongly characteristic in the fact of showing constantly, among other things, a rise in the blood pressure and a slow pulse. On the other hand, these same symptoms were called forth by anæmia of the brain experimentally induced, as was shown by the Kussmaul-Tenner ligature of the four cerebral vessels, and also later by Bastgen, Markwald, and Couty, with their injection of powders and emulsions in order to cause widespread cerebral emboli. Althann, also in 1871, showed that the effect of space diminution in the skull was identical with that of any other process which hindered cranial circulation. Therefore, concludes von Bergmann, the symptoms of compression own as their immediate cause a capillary anæmia, not by way of direct mechanical pressure on nerve

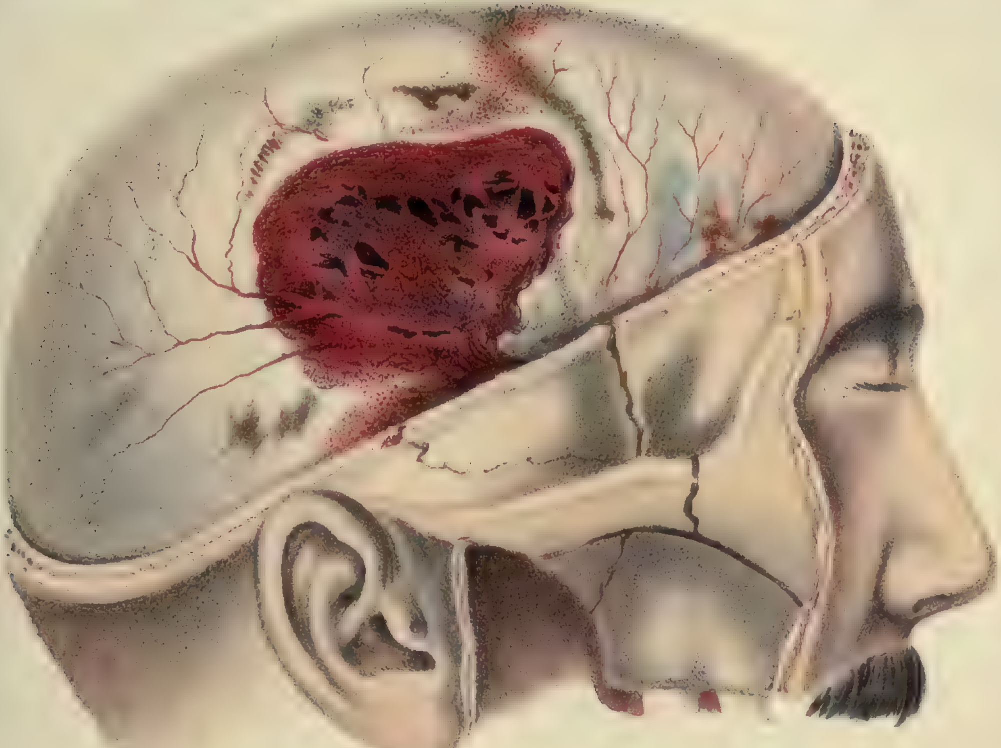
EXPLANATION OF PLATE XXXIII.

Middle Meningeal and Contrecoup Hemorrhages, with Diffuse Capillary Apoplexies. (Anger.)

FIG. I.—Compound Fracture of Cranium with Depression; Fracture of Bones of Face; Extradural Clot from Rupture of Middle Meningeal Artery.

Note the topographical relation of the hemorrhagic focus to the external orbital angle, the ear, and the zygoma, with reference to the question of trephining.

FIG. II.—Horizontal Section of Same, Showing Depressed Fracture, with Extradural Clot of no great Thickness. In the same region, directly under the dura, considerable laceration of brain substance with large intracerebral and cortical clot reaching to the pia. On the opposite side of the brain a contrecoup hemorrhage. Diffusely scattered throughout the brain, punctate hemorrhages (the "capillary apoplexies" of Bright) and minute lacerations, characteristic of severe concussion or "contusion-concussion" (Kocher). The illustration shows a marked case; frequently the punctate hemorrhages will be less widespread and less outstanding.



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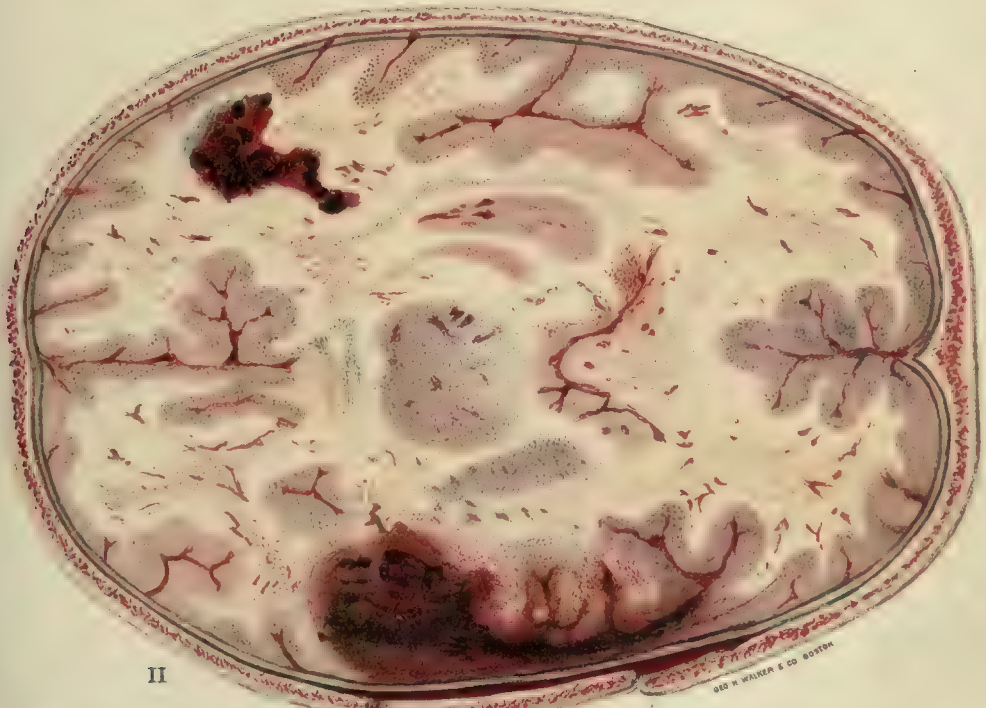


II

Middle Meningeal and Contrecoup Hemorrhages, with Diffuse Capillary Apoplexies. (Anger)

elements, but as a result of cerebro-spinal fluid tension, itself the result of space diminution. The anæmia acts as a stimulus to the vasomotor centre, causing a rise in general blood pressure; also to the vagus centre, causing a slowing of the pulse. von Bergmann further calls attention to the fact that this compression anæmia, if not too sudden, affects the various parts of the brain in a definite order, so that one area may be already paralyzed at a stage which results merely in the stimulation of others. Huguenin, indeed, had established a definite scale of susceptibility to pressure. This ran: Cortex, brain stem, gray matter of the cord, pons, and bulb; these were first stimulated and later, with the increase of compression, paralyzed in the order given; so that, to put it concretely, the cortex might be paralyzed at a stage of compression which was only sufficient to stimulate the medullary centres.

From von Bergmann to Cushing it was probably von Schultèn who advanced most our knowledge of the intimate processes of compression. He first established the definite relation existing between the rise of blood pressure and the rise in the compressing force, together with the relation of both to the intracranial circulation as seen in the fundus of the eye. He proved, for instance, the fact that it was not until the compressing force nearly reached the level of blood pressure that the latter began to rise; that, in the second place, if the compressing force were increased, it and the blood pressure continued to rise more or less parallel, the one with the other, "the blood pressure showing the tendency to exceed with its mechanism the pressure on the brain." At the end of the experiment, the vital functions being very weak, he succeeded, by still further raising the compressing force above blood pressure, in causing entire cessation of the blood stream in the retina. He showed also that the blood pressure in the ophthalmic artery ran practically on the same level as that of any of the smaller intracranial arteries.

By simultaneous measurement of general arterial pressure, of the compressing force, and of the blood pressure in the ophthalmic artery, together with a minute watch upon the coincident conditions in the fundus of the eye, he was able to anticipate the work of Cushing in a great many details—*e.g.*, the response on the part of the vasomotor centre to the anæmia caused by the compressing force, the "life-and-death struggle," as he calls it, which ensues between the vasomotor centre and the compressing force when the latter is steadily raised; the final failure of intracranial circulation as seen in the retinal vessels when the compressing force is pushed above the limit to which the blood pressure is able to respond; the rapid fall of blood pressure following this point; and, finally, the disastrous effect of lowering blood pressure (by compression of the carotid) in the presence of any considerable intracranial compression. If the retinal circulation be accepted as comparable with that of the pial vessels in the cortex, it may be said that he also discovered the special changes which occur in these vessels upon the production of cerebral compression. These were, in brief, constriction and ultimate disappearance of the fine arterioles, with stagnation in the veins of the fundus during any severe degree of compression. He recognized that the cause of the general rise in arterial pressure was an anæmia of the medulla and the consequent stimulation of the vasomotor centre.

He refers definitely to the advisability of using a window in the skull after Donders' plan, for a closer study of the cerebral circulation under compression. Yet, while acknowledging the interest such an experiment would have, he believed that the lack was adequately supplied by observation of the retinal vessels; and he laid great emphasis upon the necessity of parallel records of the blood pressure and the fluid compressing force, a point which had been neglected both by previous and by subsequent investigators until the time of Cushing's experiments. His own words had best be quoted in this connection: "As soon as the compression of the brain reaches a level such that the circulation of the blood in the medulla is interrupted, even if only momentarily, the vasomotor centre is stimulated, the blood pressure is raised, and the medulla again receives blood. Therewith, however, the origin of the stimulus ceases, and blood pressure naturally again sinks. If, however, compression of the brain persist, the circulation of the medulla will be again interrupted; a fresh stimulus and a fresh rise of blood pressure are the consequence. In this way arise the well-known undulating blood-pressure curves. If the rise of blood pressure be of short duration, we see only one wave; but if it persist for any length of time we see a series of waves. . . .

"In this way the medulla carries on a life-and-death struggle. Soon, however, the irritability of the vasomotor centre is exhausted; blood pressure is no longer supported; the medulla remains empty of blood, and the vital functions which are regulated from the medulla cease; respiration stops; the heart also, though it still goes on beating for a certain time through the influence of its proper ganglia."

In 1896 appeared the very important work of Leonard Hill, which has already been frequently referred to in the sections on the cerebro-spinal fluid and hydrostatics. His researches on compression led him to assert positively that the symptoms of this condition were due to cerebral anæmia alone, not to direct mechanical pressure on nerve tissue, and that the cerebral vessels were not supplied with vasomotor nerves. Cushing demonstrated these matters still more clearly, and we shall refer to them more fully in discussing his work.

The physiological work of recent years that has done undoubtedly most to elucidate the question of brain compression is that of Harvey Cushing, of Baltimore. Its main facts were set forth in an article published by him in 1902,* and

* Harvey Cushing: "Physiologische und anatomische Beobachtungen über den Einfluss von Hirncompression auf den intracraniellen Kreislauf und über einige hiermit verwandte Erschei-

it has received also a very full appreciation in Kocher's classical monograph. From both these sources I shall borrow largely in the following pages.

As regards methods of investigation, what was particularly new in Cushing's work was the use of the cranial window, a method which, it is true, had been used long previously by Ravina and later by Donders in the first half of the last century for purposes of studying the cerebral circulation under normal conditions, but was now for the first time used for the study of cerebral compression. The glass window was simply screwed into a one-inch trephine opening in the skull, underneath which the dura was removed; and the space thus disclosed was sufficient to show one convolution and one sulcus with the vessels lying upon it. (See Plate XXXII.) In addition he employed the injection method already used by van Stockùm,* whose results in the main he confirmed. He produced compression of the brain both by the local method and by the general. The former consisted in the introduction of a rubber bag through a trephine opening, the dura being removed and the bag filled with mercury, the pressure of which was measured by a manometer. This method, originated by François Franck, had also been used by Horsley. The latter was the old method of Leyden, frequently used after him; a method which sought to induce an evenly distributed compression of the whole brain by the introduction of salt solution into the subdural or subarachnoid space under a pressure which could be registered in millimetres of mercury by an intercalated manometer.

The reader will remember that in animal experiments the chief signs looked for are those depending on the bulbar centres and on the general cortex, not those peculiar to definite focal areas such as the motor or the sensory, which are with difficulty recognized in animals. In this sense pressure exercised generally and evenly must give more definite results than that exercised locally. With a cannula in the femoral artery, Cushing registered simultaneously on kymographs the degree of intracranial compression, that of general blood pressure, and the respiration, and at the same time through his window he was able to observe *de visu* the effects of the rise in intracranial tension upon the vessels of the brain cortex. What these effects were I may now relate; and in doing so I shall paraphrase freely from Cushing's article.

1. Injections.—A gelatinous fluid was driven in under a pressure equal to that degree of blood pressure which had obtained during the particular period of experiment that he wished to imitate. This was done usually in the agonal stage, by either the arteries or the veins or the cerebro-spinal space. His results briefly were these: When the compression pressure—that is, the pressure exer-

nungen." Mitteilungen aus dem Grenzgebiete der Medizin und Chirurgie, Bd. ix., Hefte 4 u. 5. Also: "Some Experimental and Clinical Observations Concerning States of Increased Intracranial Tension." Amer. Jour. Med. Sci., Sept., 1902, and "The Blood-Pressure Reaction of Acute Cerebral Compression." *Ibidem*, June, 1903.

* van Stockùm: "Sur la Compression Cérébrale," 7ème Congrès de Chirurgie, Paris.

cised by the compressing force—had been a little higher than that of the injection, the venous outflow was hindered; if the compression were exerted during the injection, the veins were filled with blood; if, after the injection, the veins were filled with the injection mass. Further, it was demonstrated that in the region of pressure, if this were local, and also directly opposite, in the other hemisphere, there was present capillary anæmia. In the third place he found that the transmission of local pressure was very uneven, in this confirming previous experiments of Leonard Hill and von Schultèn.

2. Observations through the Cranial Window.—The most important part of his experiments concerns the circulatory changes as seen in the cranial window. I shall here quote more or less literally from his own description:

Local Compression.—When local compression is exerted upon one hemisphere, the window being in position upon a corresponding area of the other hemisphere, the following changes in the circulation may be observed during the gradual increase in the compressing force:—One of the first phenomena consists in a color difference between the arteries and veins. (See Plate XXXII, Fig. 2.) There accompanies this a slight yet distinct widening of the veins, which extends even to the smallest radicles. When the local pressure is increased to above 80–100 mm. Hg the capillaries grow pale and the brain loses its reddish ground tone. But the large veins lying in the sulci remain filled with blood and become quite dark. The smaller venous radicles, especially where they cross the convolutions, may at this time be in parts collapsed, in parts full.

If compression be now increased so as to exceed blood pressure, the arteries themselves collapse, the veins meanwhile remaining filled with asphyxial blood. Occasionally this anæmic condition may last a long while, although usually the arteries soon fill up again, for a reason to be given. If compression has been exerted so as not to irritate the sensitive dura, this stage of anæmia may be reached with very little change in pulse, respiration, or blood pressure. The foreign body (Hg) may sometimes attain to one-sixth of the whole brain volume without causing such medullary phenomena (this explains some cases of tumor). That this is possible can be due only to one or both of two factors—either the compression is transmitted unequally, or the medulla has escaped pressure by a dislocation downward through the foramen magnum. No doubt, both play a rôle.

Horsley and Spencer have shown, and the truth of the observation is easily confirmed, that a small foreign body and a less pressure over the cerebellum, and still more so over the medulla, can cause symptoms which remain absent when the hemispheres are compressed. This observation confirms the results of Cushing's injection findings. The falx and the tentorium certainly play a great part in transmitting pressure unequally. The falx is often found dislocated to the opposite side after pressure, showing that transmission occurs mainly

EXPLANATION OF PLATE XXXIV.

Sinuses of the Dura Mater.

(From Spalteholz's "Hand Atlas of Human Anatomy.")

FIG. 1.—*Frontal Section through the Right Sinus Cavernosus*, viewed from behind. Note the very intimate anatomical relation of the cavernous sinus to the third, fourth, and sixth and the ophthalmic nerves on the one side, and to the hypophysis or pituitary gland on the other. The illustration assists in the comprehension of the pressure symptoms caused by pituitary growths, as well as the dangers of their removal; also the development of arterio-venous aneurism, the frequent cause of exophthalmos pulsans; and, further, the frequent coincidence of cranial-nerve paralyses (third, fourth, fifth, and sixth) in swellings affecting this region, whether tumor or thrombosis.

FIG. 2.—*Sinuses of the Dura Mater*, viewed from above. (The right orbit and the sinus cavernosus have been opened; the tentorium has been cut away.)

The illustration is intended to make clear the situation and course of the sinuses with reference to their injury or inflammation.

Note the communication of the orbital veins with the cavernous sinuses, representing one of the ways of escape for the venous blood under conditions of severe cerebral compression.

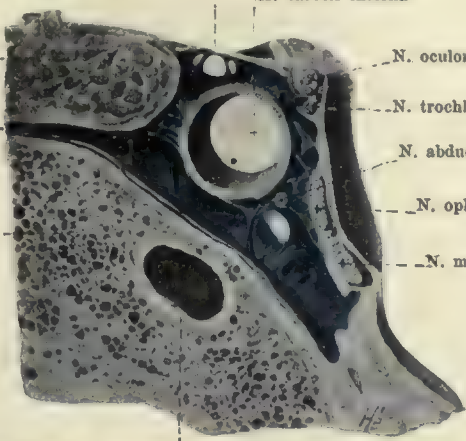


FIG. 1.

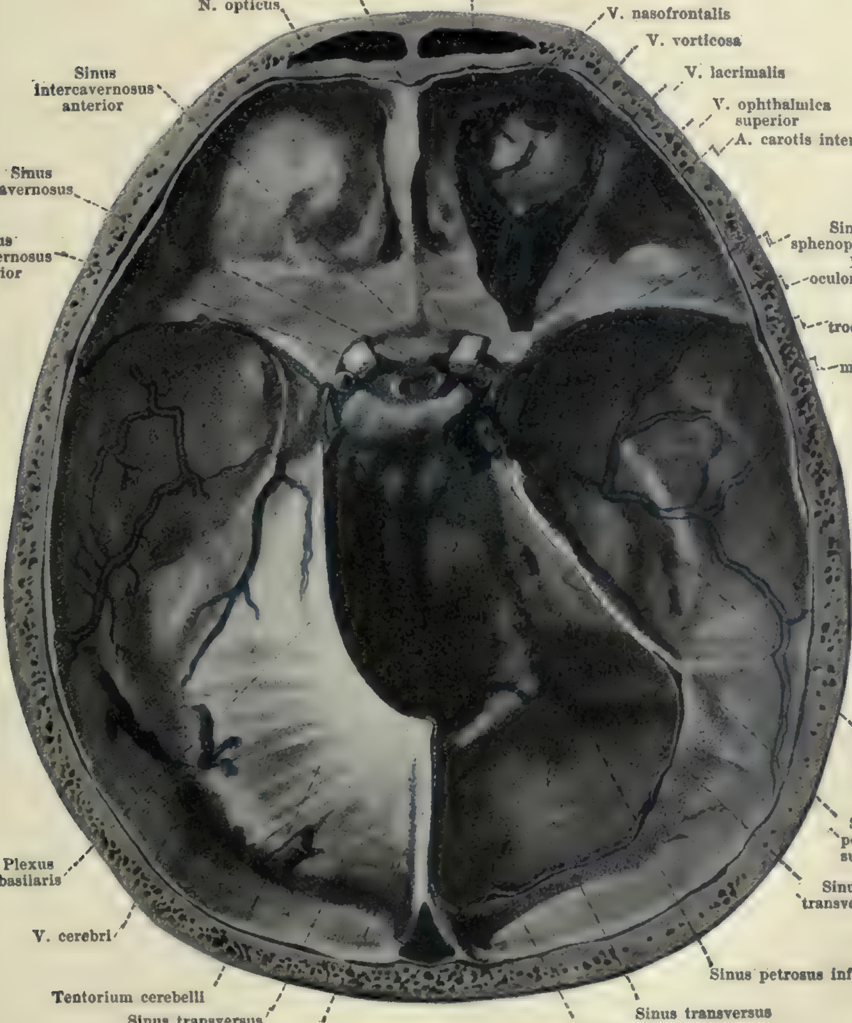


FIG. 2.

SINUSES OF THE DURA MATER. (Spalteholz.)

transversely and less in a vertical direction. The same is frequently seen in tumor cases in man (*vide* Fig. 68). The dislocation of the cerebellum and medulla downward must, again, be especially easy in animals which possess a more or less conical cerebellar fossa. In the apes and man the same condition is probably not so pronounced; although its occurrence is certainly sometimes observed.

A pretty demonstration of this dislocation downward was afforded by an experiment of Cushing's which showed that the foramen magnum can in this way be quite blocked and the cranial and spinal cavities be cut off from each other. During a high degree of local compression which had failed to call forth terminal symptoms of compression, presumably because of the escape of the medulla downward through the foramen magnum, the intraspinal tension was raised by injecting salt solution into the lumbar canal. Immediately the cardinal paralytic symptoms of compression appeared. I would add that on the clinical side such an event has been diagnosed with some approach to certainty by lumbar puncture, as pointed out by Mr. Eve (*Lancet*, April 22d, 1905, Cases 16, 17, and 20), who, in three cases characterized by increase of tension in the cerebellar chamber, was unable to draw off any material amount of fluid from the lumbar meninges. At times also in cases of meningitis with hydrocephalus, one can demonstrate a large difference in the pressure in the two cavities by simultaneous lumbar and ventricular puncture.

It is thus evident that the effects of local compression on the circulation may vary greatly in different portions of the brain, and that the symptom complex may be either very slight or very severe, according to the degree to which the higher medullary centres are affected. The greater part of the brain may be made entirely anæmic without the so-called major or medullary symptoms occurring. This is also frequently seen clinically.

General Compression.—For the purposes of drawing deductions from experiments this method is of far greater value than the local, inasmuch as the latter gives results too varying for any constant deductions. We must make sure that the increase in tension in the brain is an evenly distributed one, and this can be accomplished in no other way than by exerting the pressure through the cerebro-spinal space. Only thus can we obtain with any regularity the major and essential signs of brain compression and discover the efforts of nature to withstand their effects. Practically, it was found to make no difference at what point of the cerebro-spinal space the fluid was injected—a demonstration of the even distribution of pressure.

What are now the circulatory changes observed? As in the case of local compression, with the rise of pressure the first change is that of a slight dilatation of the veins; the appearance of the smaller radicles, previously invisible: and the development of a distinct difference in color between veins and arteries (*vide* Plate XXXII, Fig. 2). At the same time the longitudinal sinus (window in midline) shows signs of narrowing, beginning usually at the posterior end. These changes are observed long before the pressure is great enough to give signs of disturbance of the medullary circulation. Occasionally slight irritative phenomena on the part of the respiration and pulse-rate occur during this early stage, but there is no effect on blood pressure, and, if the compression be exerted slowly and carefully, these may be avoided. When the pressure has been brought up to near the blood pressure, we find the longitudinal sinus collapsed, the brain clearly in a condition of stagnation, and the veins filled and of a deep blue color. One sees this clinically also during operations in cases in which cerebral compression is marked. According to the views of some, such a degree of circulatory stagnation should be sufficient to cause marked symptoms; yet, as the curves show, there need be no change in pulse, respiration, or blood pressure. Now, according to the usual opinion, if the compression be increased above this point, and above blood pressure, a complete anæmia of the medulla will result, calling out the major symptoms of compression and causing death. An erroneous conception! What occurs is this: As soon as the blood pressure is exceeded by the compression pressure, and indeed exactly at that moment, the observer sees through the window that the brain grows pale, *i.e.*, the capillaries are emptied, and even the visible arterioles also, while the veins remain full of stagnant blood. (See Plate XXXII, Fig. 2.) This anæmia, however, lasts but a short while. Why? Because now the blood pressure rises, and rises so as to attain again a level above that of the compression pressure. Thus the blood is driven through again, the arteries become visible, and the reddish color returns to the brain. Now if we again increase the compression, the same change on the part of the blood pressure is repeated. In this way Cushing was able to drive blood pressure up to comparatively enormous heights. In one case he pushed intracranial pressure up to 276 mm. Hg and the blood pressure to 290 mm. Hg before this regulatory mechanism failed.

Moreover, it was found that a high compression pressure, if kept below blood pressure, could be borne by the brain for a long time—an hour or more. And clinically there is no doubt but that a similar condition of moderate interference with medullary circulation can be borne for days (as in hemiplegia).

Now we have here evidence of a sort of regulatory or protective mechanism designed to overcome the effects of cerebral anæmia. To what factors is this due?

It needed but a few experiments to make this clear: (i) When the vagi are cut, and general compression is brought up to a high degree, the response on the part of the blood pressure is even more regular than under normal conditions, inasmuch as the vagus effects, which otherwise frequently disturb the picture, are lacking. (ii) After section of the cervical cord, which of course cuts off vasomotor impulses, there occurs under compression only the vagus effect of slowing of the heart, and the rise of blood pressure is quite absent. (iii) When both vagi and cervical cord are cut, the increase in intracranial pressure has no effect whatever upon blood pressure. (iv) If the bulbar centres be paralyzed by the injection of a cocaine solution into the fourth ventricle, the normal tone of the vasomotor centre is abolished, and the rise of intracranial tension is not followed by any rise on the part of the blood pressure. When, however, the effect of the cocaine passes off, the usual rise of blood pressure gradually returns. (v) And finally, the abdomen being opened and a coil of small bowel exposed, Cushing could see how, during a rise of intracranial tension, the mesenteric vessels became contracted simultaneously with the rise of blood pressure, and that they dilated again as soon as pressure was removed from the brain.

In this way Cushing felt justified in formulating a law to this effect: "An increase of intracranial pressure above blood pressure causes a rise of the latter to a point somewhat above that of the former; moreover, this regulatory mechanism is due to the action of the vasomotor centre, and is brought about only by the condition of anæmia."

Before attempting to interpret these circulatory changes in the cerebral vessels under compression, it is necessary to be quite clear upon two important points: that of the incompressibility or otherwise of the brain tissue, and that of the existence or non-existence of vasomotor nerves in the cerebral vessels.

Abercrombie, in 1828, first made the assertion that the brain tissue was incompressible. Later, von Bergmann, about 1880, laid great stress on this fact, and ascribed the symptoms of compression to anæmia, the result of heightened pressure in the cerebro-spinal fluid; while on the other hand Adamkiewicz took exactly the opposite ground, and declared that the nerve elements in the brain were in themselves compressible and that this was the cause of the symptoms of compression. I need not here enter into the details of the arguments on both sides, but will simply say that Cushing's experiments demonstrated clearly the essential truth of the dependence of compression symptoms upon the circulatory disturbances and not upon compressibility of the brain tissue. In other words, the brain is essentially incompressible, although, by virtue of the expression of its fluid contents, it may be reduced in size, whether locally or generally.*

The question of the existence of vasomotor nerves supplying the cerebral vessels has also for long been a scientific bone of contention. The understanding of the action of the vasomotor centre as just described is, in fact, bound up with the question of the supply of vasomotor nerves to the brain. While earlier observers in general concluded that they were present, late researches have tended to deny this fact. Roy and Sherrington showed that the behavior of the cere-

* This statement may yet require some modification. See Sauerbruch: "Blutleere Operationen am Schädel unter Ueberdruck, nebst Beiträgen zur Hirndrucklehre." Mittheil. a. d. Grenzgeb. d. Med. u. Chir., 1907, vol. xviii., p. 939. (Gedenkband für Mikulicz.)

bral circulation in its relation to that of the general circulation was exactly similar to that of any other organ whose vasomotor supply had been cut off. They, and also Leonard Hill later, concluded definitely that such were not present; and Harvey Cushing pointed out the *non-sequitur* involved in the assumption that the brain is supplied with vaso-constrictor nerves. If the cerebral vessels under the influence of vaso-constrictor nerves were to contract, they would receive, like the rest of the vessels of the body, less blood instead of more, which they need. But the demonstration may be accepted that the brain receives actually more blood by the contraction of the vessels of the splanchnic region, as shown first by Knoll in 1886, and later to a superfluity by Cushing himself. On the other hand, Obersteiner, and later Gulland, were able to demonstrate by the vital methylene-blue stain the presence of nerves in the walls of the pial vessels, presumably vasomotor in function. Thus the burden of physiological proof is quite against their existence, while that of anatomical proof is for it. In the practical aspect we may conclude that they are absent.*

If we analyze the changes observed in these experiments, we can extract two or three facts of prime importance. First: *Under compression the obstruction to the circulation begins at the venous side and extends backward toward the arterial side.* The hindrance to the venous outflow is seen in the collapse of the longitudinal sinus and the condition of stagnation of the pial veins. Cramer, in 1880, found the pressure in the jugular vein under conditions of high compression greatly diminished (after a short preliminary rise due to expression of the blood from the skull). The venous blood, therefore, is kept inside the cranium; and inasmuch as the veins are the natural exit for the cerebro-spinal fluid, this also will come under partial stagnation and may add its quota to the picture of compression in the shape of a hydrocephalus.

Second: Very soon after the veins are pressed empty, the compressing force being constantly increased, the capillaries and the small arterioles are in their turn emptied, and we get the condition of anæmia seen in Cushing's colored illustrations. This occurs *exactly at the moment* when the degree of compression exceeds that of blood pressure.

Third: The most important fact, however, is that this anæmia—which, though impossible of visual proof in the medulla itself, is certainly present there as well as in the cortex (Cushing's injection experiments demonstrated this)—stimulates the vasomotor centre, which responds by driving up blood pressure above the level to which the compression pressure has reached. And if now compression pressure be elevated still higher, the same sequence of events is repeated. But whether it be further raised or not, there will now appear usually a rhythmic activity of the vasomotor centre which results in the well-

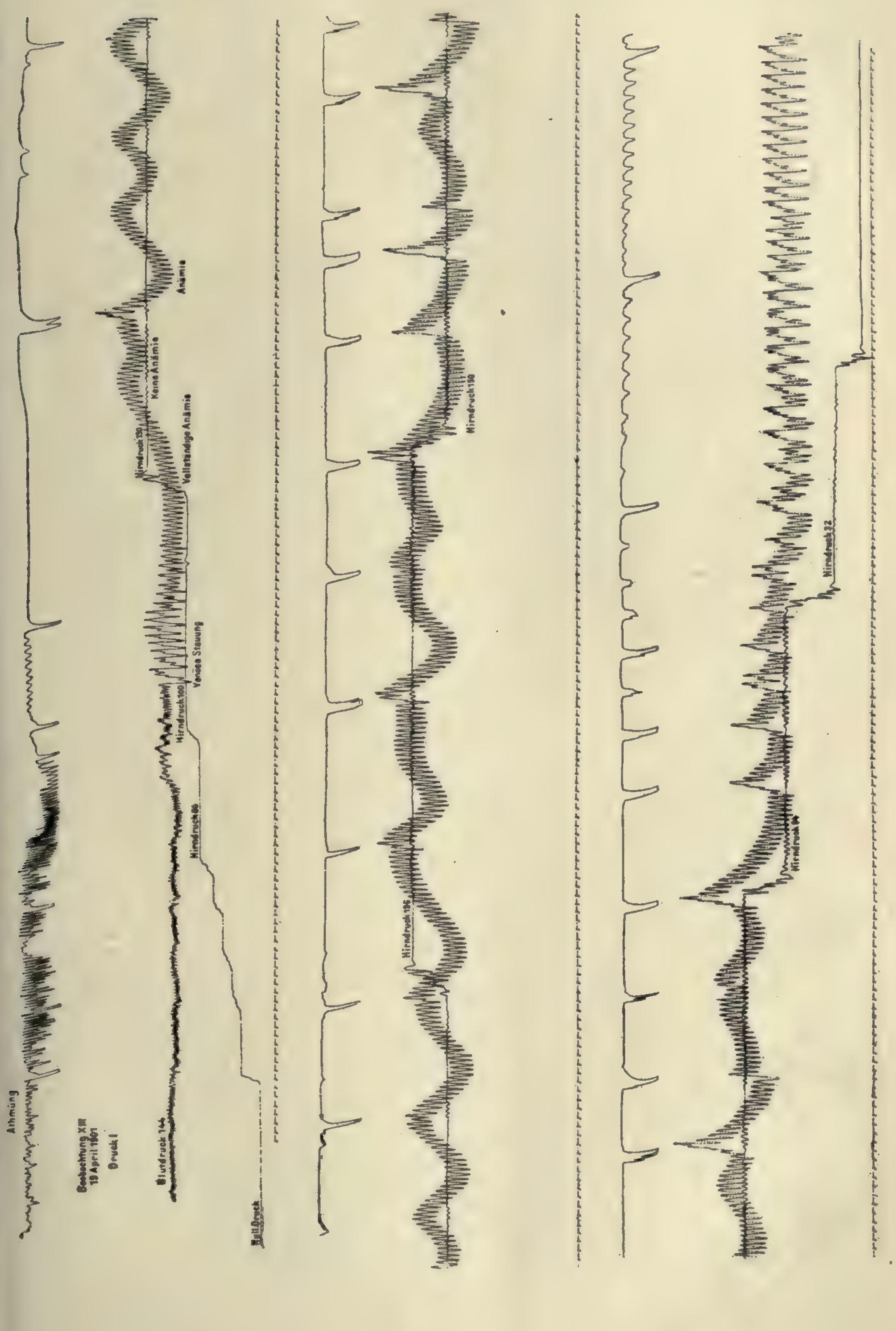
* The interested reader will find a full consideration of this subject, with bibliography, in the thesis of Auerbach, Berlin, 1905.

EXPLANATION OF FIGURE 32.

Curve Showing Relations of Blood Pressure, Pulse, and Respiration During Cerebral Compression. (Represents one of Cushing's experiments.)

Explanation of Terms:—Athmung, respiration, *Blutdruck,* blood pressure; *Hirndruck,* cerebral compression; *Venöse Stauung,* Venous stagnation; *Vollständige Anämie,* complete anæmia; *Keine Anamie,* no anæmia.

For description see text. Note the appearance of the vagus pulse with its large excursions (as seen in the "Blutdruck" record) as soon as the pressure of compression approaches the arterial level; also the answering rise of blood pressure upon the development of bulbar anæmia, and the cessation of respiration during the moments of bulbar anæmia; the development of Traube-Hering blood-pressure waves, and the gradual fall of blood pressure with the relaxation of compression. (From Kocher, *loc. cit.*, Tafel IV, p. 103.)


Athmung
Beobachtung XIV
19 April 1901
Druck I
Blutdruck 144
Null Druck
Hirndruck 80
Hirndruck 100
Venöse Stauung
Vollständige Anämie
Hirndruck 120
Keine Anämie
Anämie
Hirndruck 150
Hirndruck 136
Hirndruck 32

known Traube-Hering waves. The pulse curve rises, as explained, above the compression curve; the medulla thus receives fresh blood; consequently the vasomotor centre relaxes and the pulse curve falls gradually beneath the level of compression; the condition of anæmia thus produced again stimulates the vasomotor centre, which responds as usual with a rise of blood pressure, and so on. (See Fig. 32.)

This rhythmic activity, as Naunyn and his coworkers had already demonstrated, might go on for hours at a time. In Cushing's curves it is further shown how, if the compression pressure be raised, the blood-pressure waves follow it upward. This rhythmic activity is the direct expression of the rescuing power of the vasomotor centre. The picture involved is one of "a life-and-death struggle," to use von Schultèn's expression; who, indeed, appreciated perfectly, as far back as 1885, the essential nature of the process, but failed to demonstrate it in all its details—a "life-and-death struggle" between the compressing force and the vasomotor centre.

During all this time the effect exerted upon the respiratory and vagus centres is not lacking. Shortly before the compression pressure reaches the blood-pressure level it is seen that the breathing becomes slower and shallower, and the pulse begins to take on the character of vagus irritation—slow, and with big excursions of the style on the kymograph. This corresponds with the stage of venous stagnation while the capillaries still receive blood. Very shortly, however, after this there appears the complete, though temporary, anæmia of the capillaries and arteriolar district. Exactly at this moment respiration ceases. (See Fig. 32.) With the development of the Traube-Hering waves respiration reappears, but only during the period at which blood pressure is above compression pressure. In this fashion there develops a very much interrupted respiration which resembles in its essence the Cheyne-Stokes type.

The relation of the Cheyne-Stokes respiration to cerebral compression has lately been studied in detail by Eyster,* whose work is an amplification of Cushing's. As a result of his experiments he discovered that there were several types of disturbance of the respiratory rhythm. There is here no space to enter into any detail concerning his work; yet it is important to emphasize his demonstration of the fact that the disturbance of respiration caused by the derangement of the cerebral circulation need not at all assume the typical Cheyne-Stokes type, but may with equal significance consist merely in an irregularity both of rate and of depth, although usually there will still appear some evidence of a periodic character in these disturbances. One of his

*Eyster: "Blood-Pressure Changes in Cheyne-Stokes Respiration." Johns Hopkins Hospital Bulletin, vol. xvii., 1906; "Clinical and Experimental Observations upon Cheyne-Stokes Respiration." Jour. of Exper. Med., vol. viii., 1906, p. 565.—See also Gad. "Ueber Hämorrhagische Dyspnoë." Dubois-Reymond's Archiv, 1886, p. 543.—Sokolow and Luchsinger: Pflüger's Archiv, Bd. xxiii., p. 283.

tracings is here reproduced (*vide* Fig. 33). The clinical significance of these observations is evident.

To return to a consideration of the experiment: if in the sequence the compression pressure be gradually lowered, blood pressure will fall also, and in a parallel way (*vide* Fig. 32); but if it be continually increased, there will arrive at last a time when the vasomotor centre is obliged to give up the struggle. This is well illustrated in the accompanying Fig. 34, which reproduces the experimental fact in a clinical observation. Its defeat is marked by a rapid

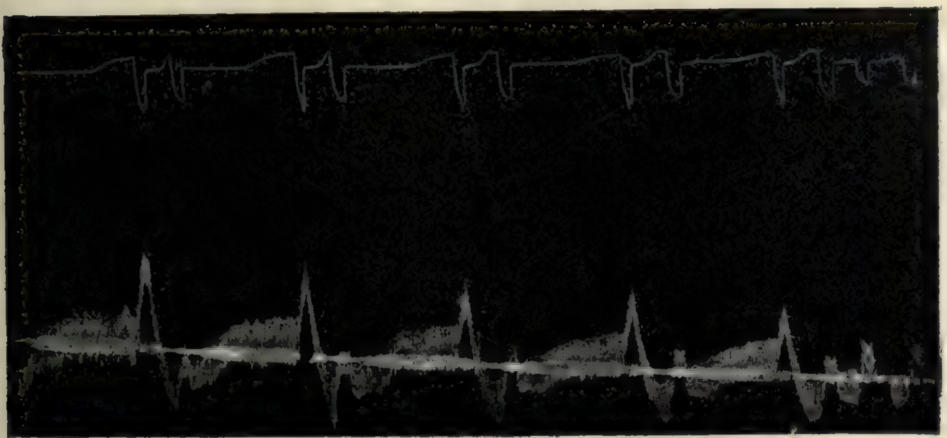


FIG. 33.—Tracing Showing Periodic Respiration and Traube-Hering Waves in a Dog as the Result of an Increase in the Intracranial Tension. (From J. A. E. Eyster, in the *Journal of Experimental Medicine*, vol. viii., 1906.) Upper line, respiration; straight line, level of cerebral compression; waving line, pulse curve, showing rhythmic variations in vasomotor action under the stimulus of the maintained cerebral compression.—Note the coincidence of the group of two respirations with crests of the blood-pressure waves where they rise above the level of the compression-pressure.

fall of blood pressure, and the rapidity of the fall is the measure of the heroic struggle it has made,—it has fought to the last gasp.*

As a result of all these physiological investigations we arrive at a summary comprehension of the subject in its physiological aspects, and this is so admirably put by Kocher that I cannot do better than paraphrase his own words: "As soon as the available space in the skull is reduced, there occurs a displacement of the normal contents. The brain itself, being incompressible, is the least able to make room. This it does by receding toward the spinal canal, so that the medulla and cerebellum are pressed into the foramen magnum and may actually cork it up. Much greater space is procured by the recession of the cerebro-spinal fluid and the venous blood. (Their paths of exit have been previously explained, and need not here be repeated.) By means of this expression of fluid and venous blood sufficient space is gained to compensate for

* It is impossible, for lack of space, to refer to the work of Maasland and Saltikoff, under Kocher's direction, as well as to that of Kocher himself upon the hydrodynamics of the circulation in compression, all of which confirms and amplifies Cushing's work.

the increased intracranial tension for a considerable time. So long as the veins, in spite of their compression, retain sufficient lumen to carry off the blood, no material pressure symptoms can appear; the only expression of this partial stagnation is the development of a papillary œdema in the fundus oculi. This period we may designate as the *stage of compensation*.

"If now with the advance of the compressing force the veins become progressively blocked in a backward direction toward the capillaries, there soon occurs

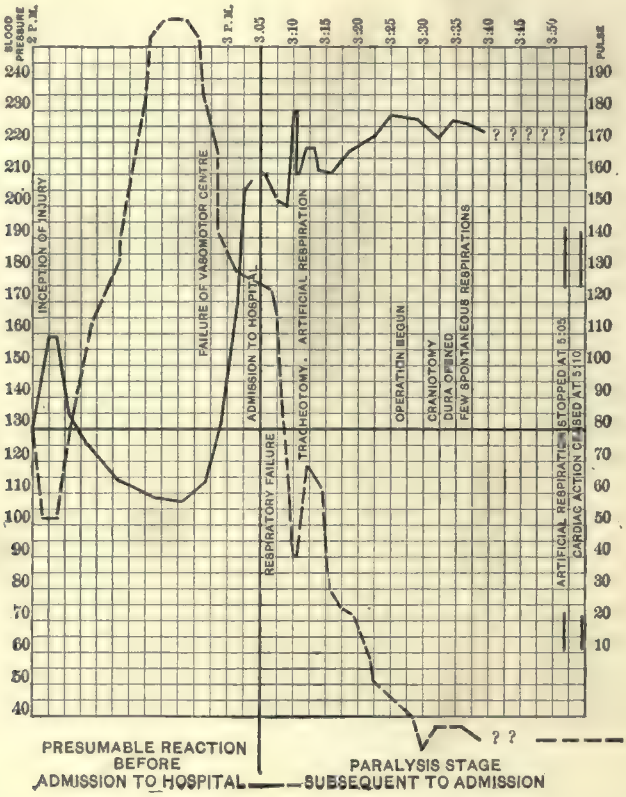


Fig. 34.—Pulse and Blood-pressure Chart of a Case of Bullet Wound of the Head, Illustrating the Course of an Advancing Cerebral Compression. First portion of chart hypothetical; the second, an actual record. (History of case on page 141.)

Broken line, blood pressure; solid line, pulse rate. (Harvey Cushing, *Amer. Jour. of the Med. Sciences*, June, 1903. "The Blood-pressure Reaction in Acute Cerebral Compression," Case V.)

a considerable cutting off of the side issues or safety exits, chiefly through the diploë by the emissaries, and there develops a considerable stagnation of the venous blood. This stage we may designate as the *beginning stage of manifest compression.* In it there is present difficult circulation (dysdiaemorrhysis) in the capillary district. There appear the symptoms of disturbed cerebral function together with those of distention of the meninges, such as headache, dizziness, pains in the limbs, restlessness, ringing in the ears, and disturbed sensorium, characterized by excitement, delirium, jactitation, and dreams.

"If the intracranial pressure be now still further increased, the compression of the veins extends backward so as to involve the district of the capillaries and the finer arterioles; and with this there develops the stage which we may call *the acme of manifest compression.* There is generalized anæmia of the brain, inasmuch as the capillaries are completely emptied. With local pressure this anæmia may remain local and permanent; and such a case will call forth only local symptoms of paralysis, such as monoplegia, hemiplegia, aphasia, hemianopsia, etc., according to the situation of the pressure. Or it may involve, if the pressure be equally diffused, more extensive areas of the brain; in such a case it can only be momentary and intermittent. It therefore gives rise to mixed symptoms of irritation and paralysis, according to the sensitiveness of the various centres to degrees of blood supply. While paralysis of the cerebral cortex through permanent and complete anæmia may be borne for a considerable time without direct danger to life, a persistent anæmia of the bulbar centres must lead inevitably to death through paralysis of the vasomotor centre. That such a result is for a certain time postponed is due to the fact that a total capillary anæmia of the vasomotor centre immediately stimulates the latter, and in this way raises blood pressure to a degree sufficient to overcome the compressing force and to drive blood once more through the capillaries. This, however, lasts only as long as the vasomotor centre is stimulated by anæmia; therefore this anæmia is intermittent, and there occur continuous alternations between dysdiaemorrhysis (lack of circulation) and eudiaemorrhysis (good circulation).

"The respiratory centre responds in a parallel way with this alternation, but in a contrary sense, in that during the stage of anæmia its function is abolished instead of being stimulated, while in the stage of good circulation it is resumed. The respiratory centre, under conditions of normal circulation, is subject to an irregularly intermittent stimulus, while under conditions of poor circulation and anæmia its function is brought to a standstill. On the other hand, the vasomotor centre in normal circulation is relatively at rest, while with anæmia it is roused to a momentary increase of function.

"It is otherwise with the vagus centre. It, in the stage of pronounced dysdiaemorrhysis (difficult circulation), is decidedly stimulated; only the stimulation in this case is not intermittent but persistent, and is therefore not dependent apparently upon the influence of the vasomotor centre.

"With a still higher degree of vascular anæmia the regulation which is the effect of the activity of the vasomotor centre becomes insufficient, and the blood pressure is able to overcome compression pressure only during systole. In diastole the capillaries remain empty, and this permanently insufficient circulation leads on to the stage of paralysis. The alternation between adiaemorrhysis and eudiaemorrhysis which characterized the 'acme of compression' has gone over into the alternation between adiaemorrhysis and dysdiaemorrhysis. From now on, paralytic symptoms occupy the foreground, and involve not only the cerebral hemispheres, but also the mid-brain and the hind-brain. This stage is introduced by periodic excitations such as tremors, nystagmus, alteration in the size of the pupils, and irregularity of the pulse and of the breathing; and this goes on to complete abolition of consciousness and of all other functions of the cerebral cortex,—to fixed, wide pupils, stertorous breathing interrupted by long pauses, rapid and small pulse, to vagus paralysis, and death, with the result of complete fall of the blood pressure."

We may add that under such conditions death probably always occurs from primary failure of the vasomotor centre, rather than from that of the respiratory, as has been asserted by some. The vasomotor centre holds the key to the position. Its defeat involves that of the respiratory and vagus centres; and with their defeat the whole army is devoted to slaughter.

Symptomatology of General Compression of the Brain.—In the present section it is my intention to discuss only those symptoms which are characteristic of compression in its general aspects; in other words, those referable to the bulbar centres and to the cortex as a whole, which are common to all forms of compression. Such symptoms as are peculiar to local pressure will be discussed in another section, and also the consideration of particular lesions.

If in the preceding pages I have gone somewhat fully into the purely scientific, that is, physiological, basis of the subject, it has been for a reason. I am convinced that the more one uses the physiological eye in estimating the significance of the symptoms of compression as seen at the bedside, the more accurately does the picture of the intracranial state of affairs correspond with the truth as revealed at autopsy or operation. I speak now not of focal conditions, but of the more general effect of compression upon the cortex as a whole, and as transmitted to the medulla.

It is to be remembered that the general, or major, symptoms of compression are called forth with regularity only by generalized pressure, and that the symptoms of local pressure are much more irregular and uncertain; in other words, we may expect a regular appearance of major symptoms in a manner corresponding more or less to that of experiment only in such cases as intradural hemorrhage, diffuse meningitis, hydrocephalus, generalized œdema, and other analogous conditions, the compressing effect of which is more or less generally and evenly distributed. Whereas with such clinical lesions as extradural hemorrhage, tumor, abscess, and cyst we may anticipate primarily focal signs and only secondarily and irregularly the major symptoms referable to the medullary centres. Further, in man one is more liable to find variations from type, as established by experiment, both in the nature of the lesion and in the response of the individual. Nevertheless, it is surprising to see how frequently and how accurately the clinical course does resemble that of animal experiment. Though the variations are many, we still recognize the type.

Kocher, in his monograph, has given us the most complete consideration of the general symptoms of compression and their correspondence with the phenomena of experimental work.

He has divided the course of an ordinary case of advancing compression into four stages, and the pathological condition in each as observed in experiments has been described in the preceding section.

The four stages may be thus summarized:—

1. Stage of Compensation.—This period is characterized by moderate venous stagnation. The main paths are narrowed, but the side exits remain open. Stagnation is insufficient to cause clear symptoms. It is important to remember that the limits of this period vary greatly in different individuals and under different circumstances; according to the normal blood pressure of the individual, to the ease of outflow of venous blood and cerebro-spinal fluid, and to the condition of cerebral circulation at the moment of compression, so will the stage be short or long. In a general way it may be said that a diminution of space to an extent greater than six per cent of the total brain mass is necessary to call forth any symptoms of general pressure. The one exception concerns the appearance of the fundus of the eye. von Schultèn, with a degree of compression representing from five to six per cent of the brain volume in rabbits, found narrowing of the arteries, dilatation of the veins, and projection of the floor of the papilla in the fundus oculi.

2. The Beginning Stage of Manifest Compression.—This stage is characterized by material hindrance to the venous outflow. There is present considerable venous stagnation (dysdiaemorrhysis). In general, the symptoms are those of irritation of the cortex and bulbar centres. Cushing showed by direct electrical stimulation that the cortex in this stage was increased in excitability. The main signs consist in the so-called reflex phenomena, due, in all probability, to sensory excitation by irritation of fifth-nerve terminals in the dura. The signs are referable partly to the medullary centres, partly to the cortex; respiration is apt to become somewhat rapid, and the blood pressure rises slightly. In addition, we find developing headache, dizziness, restlessness, roaring in the ears, in general a disturbed sensorium, with excitement, unnatural sleep, even delirium. Kocher believes that some at least of these effects are due to a direct stimulation of the cortex, and quotes the work of Spencer, which showed that definite types of respiratory disturbance followed electrical stimulation of definite parts of the cortex. It is still problematical whether much stress can be laid upon these observations or not. In a compression which is slowly increased, these reflex irritative symptoms may be quite lacking, and the third stage may develop in their absence.

One sign, however, when it is found, is very characteristic of this stage, and that is von Schultèn's eye phenomenon, which was mentioned as sometimes present even in the first stage. In experiments under conditions of more or less rapid compression, the phenomenon is constant. It must be remembered, as von

Schultèn demonstrated, that the phenomenon is apt to disappear in a few hours, always by the next day, even with the persistence of the compression. It is not to be confounded with the "Stauungspapille" or "choked disc," which condition belongs usually to more chronic and long-persisting compression, a more detailed discussion of which is reserved for the section on tumors. The present phenomenon is in reality an œdema of the papilla, caused by the forcing of cerebro-spinal fluid under tension into the optic sheath at its entrance into the orbit. Here it is supposed to exercise in a way a strangulation effect on the vessels of the nerve. It is not dependent on obstruction in the cavernous sinus, as von Graefe used to teach, but rather on hypertension in the cerebro-spinal fluid, and it disappears as soon as the latter is reabsorbed from the cranial cavity. With chronic increase in the cerebro-spinal fluid, as when a tumor is present, the simple œdema changes gradually to a neuritis, with the pathological signs of inflammation, due probably to toxins of metabolism. In such a case the ultimate result is the choked disc of optic neuritis, with its hemorrhages and atrophy, a permanent phenomenon. Clinically, I have not been able to find as yet this early œdematous condition of the papilla, probably because in suitable cases the fundus of the eye has not been examined sufficiently early, that is, before the phenomenon disappeared. Occasionally, however, the ophthalmologist has given a slightly uncertain report to the effect that the veins were somewhat dilated and the arteries small. Kocher and Cushing have both observed these changes with some frequency. Cushing, indeed, demonstrated the change in the size of the vessels on himself. During constriction of the neck with a tourniquet, Dr. Bordley was able to see with the ophthalmoscope very definite venous stasis at a manometric pressure of 80 mm. of Hg, a stasis which became quite considerable at 120–140 mm., that is, at nearly the level of arterial pressure. This was accompanied by a sensation of dizziness, nausea, and stupor, which quickly passed off when the pressure was released. The venous stasis in the fundus of the eye, of course, immediately disappeared.

A very striking observation of Cushing's concerned a patient suffering from a posterior basic meningitis, which obstructed the foramina of the fourth ventricle, and led to acute internal pyohydrocephalus; here the increase of tension was so great as to cause extreme symptoms of compression. On several occasions the ventricles were tapped without anæsthesia, and during one of these tappings Dr. Bordley followed closely with the ophthalmoscope the condition of the veins radiating toward the papilla. "Immediately on removal of the ventricular fluid, the veins which had been tortuous and much engorged became smaller in calibre and lost much of their sinuous outline, while, on the other hand, the arteries became larger, more prominent, and seemingly more tortuous."* Here we have in a striking fashion the clinical confirmation of von Schultèn's

* "The Blood-pressure Reaction of Acute Cerebral Compression, Illustrated by Cases of Intracranial Hæmorrhage." Harvey Cushing, in Amer. Jour. Med. Sci., June, 1903.

observations on rabbits. The sign, if present, is probably the most accurate we possess in the diagnosis of beginning compression, a stage which is on the whole but poorly characterized by other symptoms.

3. The Third Stage.—At this stage compression rises gradually to its acme. It is characterized pathologically by alternations of total lack of circulation with good circulation; clinically, by the appearance of symptoms indicating paralysis superadded to those of excitation of the previous stage. The respiratory centre enters upon a period of intermitting function which, however, is not always seen in the earlier part of this stage, a condition which indicates probably its paralysis as a result of anæmia; and unconsciousness becomes absolute—a paralysis of the cortex. On the other hand, the vasomotor and vagus centres are still naturally stimulated by the bulbar anæmia present. Whether this variation in the effect upon the bulbar centres be due to physiological causes or merely to an anatomical dislocation of the medulla into the foramen magnum, must be left undecided.

Clinically, the picture of compression now becomes clear; the scene is dominated throughout the stage by the efforts of the vasomotor centre to withstand the crushing effect of the compressing force; as von Schultèn put it, it is a "Kampf ums Dasein."* The more one sees of these cases and the more one considers them, the more is one impressed with the dramatic nature of the struggle.

All this has been sufficiently indicated in the previous section in which the physiological work was recounted. It remains to trace the parallelism in bedside observation. The cause of the compression—hemorrhage, exudate, or œdema—is continuing, the effect is increasing. The reflex irritative phenomena of cortical and dural origin give place to cortical paralysis, and the patient sinks into an unconsciousness of deeper, yet of varying, degree. There comes a moment when, in the experiment, the extravascular pressure (compressing force) overtops the intravascular (blood pressure), and the result must be, as Cushing saw through his window, an anæmia of the capillaries and small arterioles, a condition which immediately acts as a stimulus to the vasomotor centre. The latter responds by sending out constricting impulses to the periphery and the splanchnic regions, thus raising general blood pressure. The cerebral vessels alone are not constricted because, as we now believe, they possess no vasomotor nerves; or, if such are present, they are not constrictor. Thus the brain is supplied at the expense of the rest of the body.

In the rest of the experimental picture the vasomotor centre occupies the foreground, more particularly as regards its relation to the degree of compressing force. In man it is naturally impossible, and must remain impossible, to measure exactly the degree of compression. It is also naturally impossible to open a main vessel, as is done with animals, tie in a cannula, and record blood

* "Struggle for existence."

pressure. Fortunately, however, we have lately learned to accomplish this last in man with some approach to accuracy. And we have also learned that the height to which the vasomotor centre drives blood pressure is a measure of the severity of the compression. In 1901, when Kocher wrote, the clinical use of an instrument to record blood pressure at the bedside was practically unknown, or at least unapplied, in surgical wards; and it is the lasting merit of Harvey Cushing to have supplied this lack, and to have led the way in demonstrating the great importance of blood pressure in clinical surgery. The invention of a reliable clinical blood-pressure manometer is perhaps one of the greatest of the advances that have been made for a long time in our methods of investigation, comparable really in the writer's mind with that of the thermometer. Various types of this instrument may be procured at the shops. In the Royal Victoria Hospital we have used chiefly the Janeway instrument and Cook's modification of the Riva-Rocci; both satisfactory, but the latter perhaps the more so. Whatever may be said as to the usefulness or the contrary of this instrument in medical cases, it is incontestable that its value in helping to interpret the phenomena of intracranial compression is of the highest order. With the use, then, of such an instrument at short intervals in our supposititious case of compression, we obtain a record which, while not possessing the plainness or accuracy of the kymograph tracing in a physiological experiment, is nevertheless clear enough in its meaning to guide our judgment.

Thus if, upon the admission of the patient shortly after the accident, his blood pressure be 130 mm. Hg, an hour later 150, still later 200 or 250,—that is, if blood pressure in a given case steadily rise to far above normal,—we are immediately in possession of the fact that the available intracranial space is being steadily, dangerously reduced, and that the vasomotor centre is straining every nerve to stave off defeat. In this light the indications, whether for prognosis or for therapy, come into the field of clear vision. If, on the other hand, blood pressure keeps low, and if we can exclude certain factors such as severe concussion and alcohol, we know that there is no immediate danger to life. To be brief, this is the central fact of the whole matter.

During this period of high and increasing compression, we get usually very definite signs also from the respiratory and vagus centres. On the former the effect, upon the whole, is one first of stimulation and later of paralysis, or, at any rate, as Eyster puts it, a loss of irritability. The effect of the CO_2 of venous blood during this stage of compression, characterized at first by venous stagnation chiefly rather than by actual anæmia of the bulb, is to deepen and hasten the respiration, CO_2 being the normal excitant of the respiratory centre. Later, in the stage when bulbar anæmia is becoming more pronounced, pure anæmia being a respiratory paralysant, breathing is slowed; and if blood-pressure waves have developed, its depth varies with the undulation of the waves.

Although the parallelism with experimental findings is not so accurate as in the case of the vasomotor centre, yet, if observation be keen enough, it will frequently be found. While in experiment the rhythmic activity of the vasomotor centre is evidenced very early and very plainly in alternate arrest and resumption of respiration, as already described, this is not usually the case in the human being until compression becomes very high. Where, in a clinical case of moderate compression, the vasomotor centre is found to be working rhythmically, with the production of Traube-Hering waves, the respiration will still frequently continue regular in rate and depth. With a higher degree of compression, close observation will show that the respiration is also affected in the sense of irregular or slowed breathing at the bottom of the wave and normal breathing at the crest. It is usually a mere lessening of rate and of depth at the bottom of the wave instead of the complete arrest that is seen in experiment. With this may go that irregularity by which the respirations tend to run in groups separated by longer or shorter pauses. As compression increases, this irregularity becomes more marked, until with a very severe degree of compression typical Cheyne-Stokes breathing may develop. It would be a mistake in a case of moderate compression seen at the bedside to expect typical Cheyne-Stokes breathing; yet, when the latter does develop, it is very easy to determine, by means of the blood-pressure manometer, that the period of respiratory activity corresponds fairly well with the rise of the blood-pressure curve, and that of apnœa with its fall. What it is especially important to recognize is the fact that it is necessary to observe very closely not only the rate of respiration, but also its depth and its regularity. Minute changes in all these respects, but especially in that of the last, may give us an early hint of the struggle of the vasomotor centre, and indicate very plainly an advancing compression.

The work of Eyster, so far as I know, is the first that presents an accurate and continuous record of blood pressure and respiration in the human being, under conditions of cerebral compression. This he was enabled to do by the use of Erlanger's instrument. In one case of tuberculous meningitis, in which compression became marked, typical Cheyne-Stokes breathing developed. A decompression operation, while ultimately insufficient to ward off a fatal issue, relieved entirely the respiratory disturbance. Eyster took very numerous records during the few days that this patient lived after coming under observation, and was able to demonstrate the important fact that great variations might occur in the derangement of respiratory action under compression. He found four distinct types: (*a*) Groups of respirations of approximately equal depth; (*b*) descending groups in which the first inspiration was the largest; (*c*) groups of irregular depth; and finally, (*d*) groups which presented the typical ascending and descending character of Cheyne-Stokes breathing. He found also that it was not the last that was most common, but rather those of irregular respirations, and those of the gradually decreasing type. He confirmed also the general observation that the groups of respirations are constantly associated with a rise in blood pressure and an increase in the rate of the pulse; while in the periods of apnœa there was a fall of blood pressure and a gradual slowing of the pulse, which reached its greatest development coincidently with the lowest point of blood pressure. Moreover, with the disappearance of the periodicity of respiration there was also a disappearance of the blood-pressure waves and of the variations in pulse-rate. It may be remarked parenthetically that Eyster found also, as had Cushing before him, evidence of the effect of blood-pressure waves upon the cortex and the mid-brain. During apnœa the pupils dilated, the eyeballs were rotated upward and outward, and the patient became unconscious; during the periods of respiration the pupils returned to their former size and the patient became perfectly conscious. These phenomena, too, were coincident with the rise and fall of the blood-pressure waves. I have been able upon different occasions to observe at the bedside this periodicity in the depth of unconsciousness and in the size of the pupils, as well as the varieties of respiratory disturbance described. One will even find such variations entered in the nurses' notes. Trotter,* also, has made observations along this line which agree in the main with those described.

The effect of compression upon the vagus centre is seen in the so-called vagus pulse, a pulse characterized not only by slowness, but by its regularity and by a certain tension in the artery. It has long been regarded, perhaps wrongly, as the most constant and valuable of the signs of compression. In experiments it usually begins early, even before the disturbance of the cortex as seen in somnolence; and it is apt to persist late in advancing compression. While due to an anæmia of the centre, it is nevertheless not easily influenced by the circulatory variations of the Traube-Hering waves of blood pressure. In other words, the slow vagus pulse persists with extraordinary regularity throughout compression, until it nears the stage of paralysis. It is true that close and continuous observation would perhaps bring to light a greater correspondence with the slight changes of rate that one sees in experiments, but this is difficult at the bedside. The very persistence of this pressure pulse, this lack of change to correspond with changes in the blood pressure, make it a poor sentinel, as compared with the respiratory or the vasomotor centre. Though it shows itself early, its paralysis is usually long deferred; therefore its value is great in indicating the mere fact of compression, but small in measuring the degree of that compression and the remaining resisting power of the vasomotor centre. The degree of slowness at any given moment often does run parallel, roughly speaking, with the degree of compression,—the greater the compression, the slower the pulse,—yet often this does not at all hold true; and Kocher has emphasized the fact that sometimes the slow vagus pulse may never appear at all. This, too, I have had not infrequent occasion to confirm. Various reasons have been given in

* Trotter: "Cheyne-Stokes Phenomenon in Acute Cerebral Compression." Lancet, May 19th, 1907.

explanation of this fact. Thus, in cases where the dura mater, as well as the skull, is opened, and by that fact intracranial tension relieved, it may be absent. The presence of fever may hasten a slow pulse to the point of making it a normal one; or, again, the stage of paralysis with its rapid, running pulse may have been reached by the time the patient comes under observation. Moreover, as I believe, the coincidence of the shock effect of concussion will in some cases prevent the vagus stimulation effect from appearing. Thus, it is important not to place too great reliance upon the absence of the vagus pulse, if coincident signs from the other centres indicate compression.

In conclusion, it is well to emphasize the fact that to the influence of the anæmia of compression the respiratory centre is perhaps the most sensitive; and that, while the vasomotor centre is the strong tower of defence, it is the respiratory disturbances that offer the earliest index of the degree of compression and the resisting power of the vasomotor centre. Certainly they give the earliest warning of the weakening of that resistance. So long as respiration is good, there can be no immediate danger. If changes in the respiratory rhythm, depth, and rate become plain, it is a sign that one is nearing the danger zone; in other words, that the vasomotor centre is approaching the breaking-point. I would like also, at the risk of repetition, to lay stress upon the necessity of close and long-continued observation. It is not sufficient to judge, as is so frequently done in a rough-and-ready manner, the degree of compression, by merely feeling the radial pulse and estimating its slowness. It is necessary also to use the blood-pressure manometer, and to observe the minute details of respiratory activity; and to do both at short intervals.

Now, while the bulbar signs are probably the clearest and most important of this stage, the phenomenon of unconsciousness, as the evidence of pressure on the cortex, gives also a clear picture of the progress of compression. We believe that unconsciousness in its varying degrees is the effect of an anæmia of the general cortex.

And we can differentiate two distinct degrees in the disturbance of consciousness: first, that of irritation; second, that of abolition of function. In describing the preceding stage of beginning compression, attention was called to the irritative interference with cortical function characterized by restlessness, ill-regulated movements, crying, groaning, delirium, etc. While these symptoms usually indicate the earlier stages of compression, it is important to remember that, clinically, they often extend into the third stage, that of manifest high compression, in which complete unconsciousness is the rule. As Kocher remarks, they have frequently been held to indicate contusion or laceration of the brain, as opposed to mere compression, and as the evidence of inflammatory reaction. This is a mistake. The same picture is not infrequently seen in instances of pure compression without laceration, such as those of middle meningeal hemorrhage.

The stage that we are at present discussing, however, owns usually as its characteristic picture the second degree of cortical disturbance, that of true unconsciousness. Here we have all the various grades of somnolence, stupor, and complete coma. It may be said that this abolition of cortical function practically always precedes bulbar paralysis. It is important, however, to note that while unconsciousness is an essential sign of compression, yet, for early diagnosis and effective treatment, it is a mistake to wait for the appearance of developed coma. One should learn to regard the earlier irritative signs as very important evidence for the early diagnosis of compression; and it is not exceptional to see cases where these alone are present (delirium, restlessness, etc.) at a stage when the bulbar centres are already becoming paralyzed. Kocher relates an instance where to the last the patient was throwing himself around, had hallucinations, opened his eyes when crying out, gave evidence of pain upon the prick of a needle, whose skin reflexes were still present, and tendon reflexes exaggerated—all this at a time when death was imminent.

4. Fourth Stage.—The fourth stage is that of paralysis, characterized pathologically by alternations of complete anæmia with difficult or partial circulation. Here all the symptoms of irritation disappear, giving place to those of paralysis. That of the cortex is evidenced by the deepening of the unconsciousness which hitherto may have been only partial; the patient sinks into coma; the limbs become flaccid. That of the bulbar centres is betrayed by irregularity of respiration, with the ultimate development, frequently, of Cheyne-Stokes breathing; by the gradual failure of the vagus centre, with the appearance of a rapid pulse; and by a decrease and ultimate failure of the resistance of the vasomotor centre, with consequent fall in blood pressure, which, just before the end, sinks rapidly toward zero.

Between the third and fourth stages there may often be made out a transition period during which one may detect slight evidences of the approaching paralysis of the bulbar centres. It is frequently introduced by a beginning irregularity of the respiration and of the pulse, together with certain movements in the eyes and changes in the pupils. As already mentioned, respiration, upon close observation, may show irregularities in depth, rate, and rhythm, which may go on to a definite grouping, and ultimately arrive at typical Cheyne-Stokes breathing. Parallel with these run often variations in the strength and rate of the pulse, and in the middle of a series of slow pulse-beats (vagus irritation) there may appear a series of rapid and small pulse-beats, indicating a temporary paresis of the vagus centre. With this one may also see a more or less rhythmical dilatation and contraction of the pupils. During this period one may easily detect, with the blood-pressure manometer, Traube-Hering waves, as already described. These slight indications on the part of the bulbar centres should be carefully hunted for. If they are found, their significance is very great, because they indicate the approach of the paralytic stage and warn to immediate action if such be at all indicated.

It may be remarked parenthetically that it is not necessary for the development of the paralytic stage that the compressing force should steadily increase to a point of overcoming the vasomotor resistance; the compression pressure may have been stationary for some time, as, for instance, in some cases of death from middle meningeal hemorrhage where a clot at post-mortem examination is found coagulated, old. In such a case we must assume that the persistence, even of a stationary pressure, may wear out and ultimately paralyze the vasomotor centre, whereupon blood pressure falls and death occurs. Of course in some cases of this nature it is certain that a progressive cerebral œdema may still further diminish the available intracranial space, and in that sense act as an increase of the compressing force.

The cortex in cases of general compression is usually paralyzed before the bulbar centres; indeed, it is not infrequent to see coma becoming more and more deep while the bulb seems to be escaping. Such an event must be due either to an escape of the latter into the foramen magnum, or to an uneven distribution of pressure; in any case, however, it means a grave prognosis. In analyzing the charts of fatal cases of compression I have been impressed with the frequency with which death seemed to ensue, not from paralysis of the vital centres, but from pneumonic complications. That these are the direct result of coma alone, which acts by allowing an inhalation infection, there can be little doubt. On the other hand, one may see cases in which unconsciousness remains of very light grade, while death is evidently due to bulbar paralysis. In such we find usually that pressure, though generalized, has been greatest in the subtentorial space.

The respiratory centre is, in experiments, by far the most easily paralyzed by circulatory disturbances. This is not seen with the same distinctness at the bedside, unless one substitute for the complete cessation of respiration seen in animals a mere slowing or disturbance of rhythm as seen in man. Toward the end, however, just before death, the parallelism is better maintained. In most cases of compression death seems to result from respiratory failure, inasmuch as breathing ceases while the heart continues to beat; and Sir Victor Horsley* has emphasized this fact. Cushing, however, pointed out that probably in all cases this respiratory failure is antedated by that of the vasomotor centre. When the latter can no longer succeed in forcing blood into the medulla, the respiratory centre is the first to show the effect; yet it is the vasomotor centre that is primarily at fault; it holds the key to the position. Druif, in spite of continuing very high cerebral compression, could not kill his animals so long as he kept up artificial respiration; at least, the heart continued to beat as long as he continued it. And in clinical cases this procedure has kept the heart going for long periods—in one of Cushing's cases twenty-three hours—after the vasomotor

* Sir Victor Horsley: "On the Mode of Death in Cerebral Compression." Quarterly Journal, London, 1894.

centre had given out and blood pressure had fallen to its paralysis level. It is doubtful whether during such a condition, though the heart continue to beat, the brain or medulla is receiving any blood whatever. Probably not, inasmuch as consciousness does not return nor does blood pressure rise. We may believe, however, that at the beginning of the vasomotor failure, when respiration begins to show the effect of anæmia and the general blood is therefore the more poorly oxygenated, there becomes established a vicious circle. The inferior blood which is the result of the respiratory paralysis must have an unfavorable effect upon the vagus and vasomotor centres and leave them ultimately less able to continue the fight. On the other hand, the respiratory centre may always be revived, provided the vasomotor centre give it new blood.

The paralysis of the vagus centre is evidenced by the development of a rapid, small pulse. No matter how great the pressure, the heart is never brought suddenly to a standstill; that is seen only as an inhibition phenomenon upon the sudden application of high pressure, as in concussion.

The vasomotor centre, as already said, is the last to be paralyzed. At a time when the respiratory centre is showing signs of giving up, the vasomotor centre is driving blood pressure higher. The severest degree of compression which we can employ paralyzes the respiratory and vagus centres, but only drives the vasomotor centre to increased action. When the latter becomes exhausted, blood pressure falls and the prognosis becomes extremely grave. The vasomotor centre is the "ultimum moriens," and its paralysis alone sets the seal upon death. Clinically, we observe profound coma, fixed dilated pupils, stertorous, irregular respiration, occasionally of the Cheyne-Stokes type, a rapidly running pulse, becoming gradually imperceptible, and ultimately death by cessation of respiration, the heart continuing to beat for some minutes afterward, probably by virtue of the action of its intrinsic ganglia.

I shall here quote briefly one or two of Cushing's cases, and add one or two personal ones, to illustrate the importance of keeping a watch on the vasomotor centre by means of the blood-pressure record:

Cases illustrating the second stage, that of beginning manifest compression, are frequently seen. Thus: A boy aged 12 (Surgical Case Reports, Book 87, page 5, Royal Victoria Hospital, Dr. Bell's service) fell upon his head from a height of about ten feet. A skiagram later showed that he had sustained a fracture of the right frontal bone running horizontally backward to the parietal. There was no immediate unconsciousness. About ten minutes after the accident, he vomited and began to feel drowsy. By six-thirty he had become quite unconscious and had a convulsion. He was unconscious for about three hours, during which time his blood pressure ranged from 96 to 100, while his pulse was in the neighborhood of 100, and respiration 24 to 26. There were no localizing signs. He was quite restless, resented interference, but could not be got to respond to questions. Two hours later he began to recover consciousness; a little later he was quite clear. All this time blood pressure did not go above 100. In this case there was evidently present, as a result of his fracture, a certain amount of basal hemorrhage, sufficient to cause unconsciousness, but insufficient to call forth any symptoms on the part of the medulla. It was the early stage of manifest compression.

One of Cushing's cases illustrates a slightly more severe degree of compression, still belonging to the stage under consideration. (Case 2, *loc. cit.*)

Here, in a man, there was present simple fracture of the base with a mild degree of compression, and with intermeningeal hemorrhage as proven by lumbar puncture. The pulse went down to 63; blood pressure rose as high as 185 mm. of Hg. During the subsequent twenty-four hours frequent observations on the pulse-rate and arterial tension were taken, and as the latter did not go above 185 it was considered a safe level, and it was concluded that there was no indication for operation. The process of compression was arrested at a stage "in which there could be no apprehension lest the vasomotor centre become fatigued in its regulation of blood pressure." If the latter had gone much higher, operation might have become urgent.

In illustration of the third stage, that of the acme of manifest compression, Cushing gives an account of a very remarkable and convincing case, one of apoplexy, in which symptoms of high intracranial tension showed themselves in the blood pressure, which rose as high as 300 mm. Hg.

"The patient was admitted to the hospital thirty-six hours after the onset of the symptoms. He was in profound stupor; the right side was in a condition of complete paralytic flaccidity; temperature was 99.6° F.; respiration varied from 21 to 27 and was characterized by a distinct periodicity, shallow and stertorous periods alternating with considerable regularity; pulse 50 and of high tension; blood pressure around 300 mm. Evidence of vasomotor rhythm was at times observable, the height of the blood-pressure wave corresponding with the period of deeper respiration, with restlessness and movements in the non-paralyzed side, and with some pupillary dilatation. It is unnecessary here to go further into the symptoms. The history, though very meagre, indicated that the patient's stupor had been increasing, and in view of the great elevation in blood-pressure, and beginning evidence of respiratory implication, it was determined to make an attempt to relieve the intracranial tension, and if possible to locate and evacuate the clot. A large Wagner flap was turned down from over the left hemisphere; the dura was tense and without pulsation; on incising it, the brain bulged far into the opening and began actively to pulsate. The convolutions were greatly flattened, deeply cyanosed. A probe was passed through one of the convolutions behind the fissure of Rolando, and at a depth of 4 mm. entered the cavity; dark, blackish, fluid blood spurted out along the groove of the instrument. There followed the evacuation of about two teaspoonfuls of old discolored semifluid clots." Cushing's blood-pressure chart (see Fig. 35) is here reproduced. The reader will see how extraordinary was the effect upon blood pressure of this relief from compression. Within twenty minutes it had reached a normal level, falling about 230 mm. of Hg. The pulse meanwhile remained at its former rate of around 60, evidencing the usual persistence of the effect on the vagus centre even when compression is relieved. A glance at the chart shows the permanency of this relief from compression. Unfortunately, the patient died on the third day from pneumonia, after having, nevertheless, shown definite improvement in his compression symptoms.

While this case is a most remarkable one from many points of view, it is not the less so as a demonstration of the parallelism between the clinical event and physiological experiment.

The phenomena of this stage, and the effect of operation in lowering a dangerously high blood pressure, might be graphically set forth in numbers of blood-

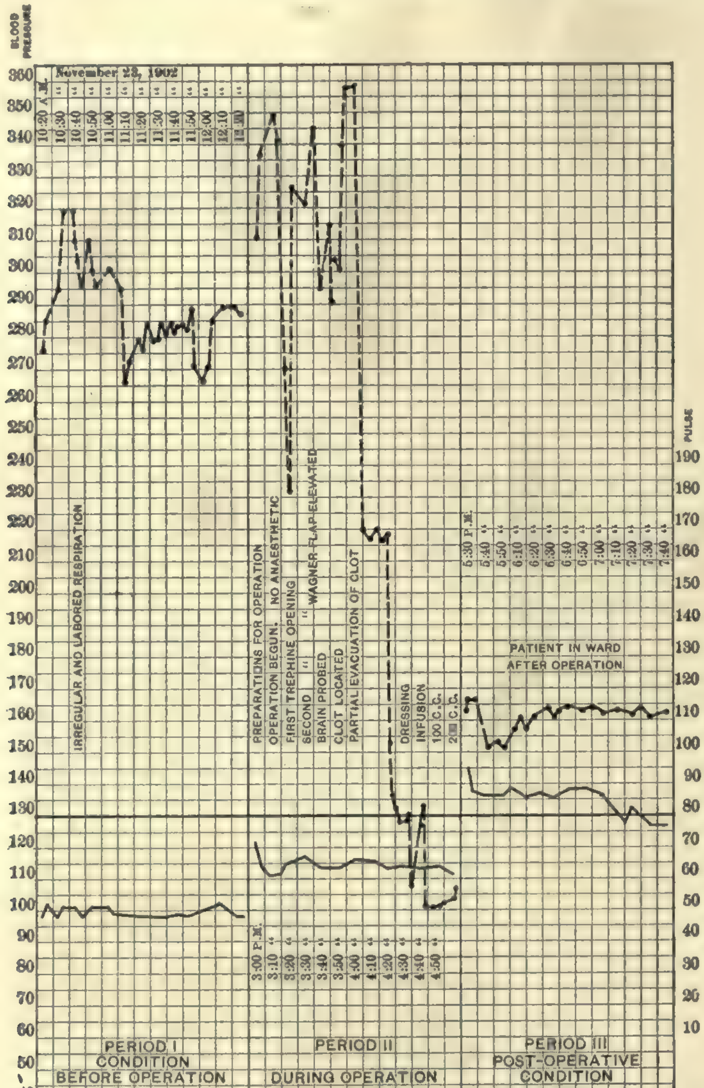


Fig. 35.—Broken Line, Arterial Tension; Solid Line, Pulse Rate. Three fragments of the blood-pressure chart of Case IV. Note, in Period I., the high tension and slow pulse; in Period II., the release from the vasomotor overaction by the craniotomy and evacuation of clot, causing a fall of blood pressure of 260 mm. of Hg, with rise of the pulse rate to normal; in Period III., the practically normal levels after operation. (From Harvey Cushing's article on "Blood-pressure Reaction," in the *American Journal of the Medical Sciences*, June, 1903.)

pressure charts,—charts which have been made in the last two or three years by many surgeons who have adopted the use of the clinical blood-pressure manometer. But it is hardly necessary to emphasize the argument by what might be needless repetition. I shall add but one (Fig. 36, on page 174) in order to show the form of chart devised by the writer for use in the Royal Victoria Hospital. The noting of the character of respiration (and the nurse soon learns to detect and describe irregularities), as well as its rate, and the details as to pupillary changes are of great value in increasing one's clinico-physiological knowledge.

The fourth stage, that of paralysis, may also be represented graphically, although in such cases there is frequently little time or opportunity to make frequent measurements of blood pressure. In one case I had the opportunity of observing this development from the acme stage, and was enabled to make several blood-pressure records.

It was that of a jockey, who was rendered unconscious by a fall from his horse at 5 P.M., and was brought to the Royal Victoria Hospital. No definite localizing signs. At 8:30 P.M., pulse 40; at 8:40, blood pressure 190 mm. Hg; at 9, pulse 57; at 9:05, pulse 64; at 9:15, blood pressure 190; at 9:30, pulse about 74. At this point 15 c.c. of blood-tinged fluid were withdrawn by lumbar puncture. This seemed to change the whole aspect of affairs; he quickly grew cyanosed, respiration became Cheyne-Stokes in character, the pulse grew rapid and small, and the blood-pressure quickly sank; this all within five or ten minutes. Artificial respiration kept the heart beating for a half-hour longer, but to no avail. At post-mortem examination a large intracerebral clot was found. Here evidently, from 8:30 o'clock on, the vagus was becoming paralyzed as shown by the increasing rate of the pulse; blood pressure had probably been higher than 190 and was on the brink of giving out. The lumbar puncture, by removing some of the support from the spinal canal, presumably let the bulb be squeezed down into the foramen magnum and against its rim, and thus, by acute pressure on the bulbar centres, gave the finishing touch to the beginning vasomotor paralysis, with consequent rapid fall of blood pressure, which in its turn induced complete vagus and respiratory paralysis. Note the implied warning against withdrawing any material amount of spinal fluid.

Cushing's article contains a very clear example of this stage also.

A young woman was brought into the hospital with a gunshot wound of the skull. About one hour after her admission she was in deep coma; respirations were slow, gasping, and irregular, with periods of apnœa; pulse was rapid, 160; and the arterial tension low. "Blood-pressure observations, which were immediately instituted, demonstrated that a very rapid fall was taking place. The eyes were fixed, staring, and prominent, with widely and equally dilated pupils. The patient was hurried to the operating-room, but before anything could be done, respiration ceased altogether. Under artificial respiration the bone flap was turned down, the dura widely opened, and a large amount of blood-clot was evacuated. The good effect was shown in the patient's taking for the first time a few spontaneous gasping respirations. These, however, did not long continue. The blood pressure, meanwhile, had been steadily and rapidly falling until it had reached its level of complete vasomotor paralysis, representing only 20 to 30 mm. Hg, a condition from which there is probably no recovery. Artificial respiration was kept up for two hours longer before its final abandonment." As Cushing remarks, "As long as there is cardiac pulsation, it is difficult to bring one's self to a realization of the actual presence of death." The accompanying blood-pressure chart is self-explanatory. (Fig. 34, on page 126.)

Diagnosis of General Compression of the Brain.—Great as is the value of a knowledge of physiological principles in considering a question like that of compression, it would be asking too much to expect that compression in the human being should reproduce regularly the same march of symptoms as does compression in animals. In the one the factors of the experiment are controllable, in the other they are not. In fact, the exact division of the experimental picture into successive stages which remain more or less separate and distinct is frequently not discoverable in the human being. The variations are due chiefly to variations in the conditions of the process. Whereas in the animal a definite amount of compression can be applied in a definite unit of time, in the human being that compression is apt to be spread over a much greater period of time, with a much greater variety in location, with great difference in the rate of progress, and with the frequent coincidence of outside features, such as alcohol, concussion, and other things inherent in the physical state of the individual at the time of injury. Nevertheless, in those clinical conditions in which compression is generalized and advances with a certain degree of rapidity, such as in the basal effusions of free hemorrhage, meningitis, and hydrocephalus, the experimental picture is often more or less accurately reproduced; while the effects of localized pressure, such as those of tumor, cyst, or abscess, often fail to call forth the typical signs of compression by reason of the slowness of their advance. Yet, in their terminal stages, when they become complicated by hydrocephalus, they may show quite as clearly the picture of acute advancing compression and run quite as rapid a course as those in which the compression is primarily generalized. Diagnosis, therefore, apart from the recognition of the possible cause, consists in the disentangling of the symptoms which have been discussed in the preceding sections.

In a general way, compression has to be distinguished from concussion, and, if we adopt the old classification, from contusion also. Where a history is obtainable, the pathogenesis often decides the matter. Where a single, sudden pressure has been exercised, as from a blow, the old rule holds good, that the appearance of symptoms in their full intensity with succeeding gradual disappearance, indicates concussion; focal signs, if they appear immediately, speak for contusion; while the late appearance of symptoms speaks for compression. The free interval—and by that is meant not only the lucid interval before the onset of unconsciousness, but also the late onset of any focal sign such as paralysis of any kind—speaks always for compression, no matter how short it may be. In the later course the symptoms of concussion subside; those of contusion are apt to increase, with the addition of symptoms referable to injury of parts in the immediate neighborhood of that originally injured, chiefly by the development of reactionary œdema; and, finally, in compression the symptoms spread so as to involve remote areas, particularly those of the medullary centres.

The uncomplicated cases of each of these three conditions are easy to separate. The difficulty arises when two or all three are coincident. The symptoms of compression frequently come on before those of concussion have passed, and in either case the focal signs referable to a tear in the brain substance or to the compression of effused blood may be entirely masked by complete unconsciousness. When a diagnosis is impossible, we must decide upon that condition which gives the strongest indication for treatment. In concussion no operation can accomplish anything; the damage is all done. In contusion Kocher advises operation to remove necrotic brain tissue and clot if localizing symptoms exist. In compression, operation is definitely indicated.

Perhaps the most important point in the diagnosis of compression is that the slow pulse of vagus irritation must not be expected with any regularity, nor must operation be deferred because it is not present. Neither should one wait for a deep degree of unconsciousness. In the paralytic stage the differential diagnosis is usually impossible.

The Treatment of Cerebral Compression.—There are naturally two general indications to be met: the removal of the cause and the increasing of available space. While these indications are in a measure absolute for the severer stages of compression, they are naturally not so clear when compression is not great. Here nature will frequently relieve the condition unaided, if the cause of the compression (blood-clot, exudate) be remediable at all by natural processes. Surgical judgment is necessary to determine whether nature can do it alone, or cannot do it without help. The indications that depend on special causes will be discussed in the corresponding sections. In this place we need only refer in a general way to the principles of surgical treatment. It is evident, of course, that in very many instances the removal of the cause and the increasing of the intracranial space can be accomplished only by operation. In former days, however, when operation was less a current matter than now, various measures of a medical nature were recommended. The aspect of the patient suffering from severe compression, whose turgid, congested face we now know to be due to the compensatory enlargement of the superficial veins for an obstructed intracranial circulation, and the patient's high-tension pulse, which we also have learned to regard as the saving effort of the vasomotor centre, very naturally indicated to the medical man of former times the necessity for venesection and for drugs that lower the blood pressure. And the wisdom or folly of venesection has for long been much discussed. It may be said that during the acme stage of compression, when the bulb is threatened with anæmia, any measure, whether venesection or the use of depressing drugs, that lowers blood pressure is absolutely contra-indicated; and this fact was long ago emphasized by Falkenheim and Naunyn as the result of their experimental observations. On the other hand, in the early stages of compression, and perhaps particularly in the irritative inflammatory conditions of the meninges accompanied by high fever and rapid pulse, the value of venesection is in many cases undoubted. Here probably it actually relieves the definite congestion in the meninges. At any rate, the sedative effect of removing a few ounces of blood in the delirious stage of meningitis is very marked.

When we come to consider the advanced conditions of compression, where the medullary centres are struggling for life, and where action is urgently indicated, operation comes into its right. The particular nature of the interference will vary with the nature and situation of the cause. There are, however, certain dangers of operation in the late stages which should be mentioned. In the first place, the nearer a patient is to bulbar paralysis, the less is the likelihood that operation will save life. When the centres have been long compressed, they do not always recover their activity upon relief of compression; or, if they do, this may be delayed. Moreover, a sudden relief of high pressure is actually damaging in its effect; at least for the moment. The indications are to supply, as quickly as possible, good oxygenated blood to the centres, and to disembarrass them of the stagnating venous blood. This can be done only by raising the blood pressure and stimulating pulmonary action; possibly also by inhalations of oxygen. The various methods of raising blood pressure consist in artificial respiration, where necessary, in a proper filling of the heart and cerebral vessels by lowering the head, by bandaging the extremities, and by rhythmical compression of the abdomen, together with the cautious use of intravenous salt solution. These are the measures for an emergency. Certain drugs also are of value, especially strychnine, which, according to Cook's observations,* does much good. Adrenalin has been advised by Crile,† with the precautionary remark that its effect is very fleeting; and a solution of sodium carbonate has been recommended by Howell.‡ With regard to adrenalin, it may be well to call attention parenthetically to the good effect obtained by the repetition of its administration, as seen in the patient whose history Butler relates.§

All these are emergency measures intended to save the patient's life temporarily, and give time for operation to remove the cause and enlarge the intracranial space. It must be remembered that the stimulus of compression upon the vasomotor centre is lost when operation relieves that pressure, and this stimulus

* Cook and Briggs: Johns Hopkins Hospital Reports, 1903.

† Crile: "Blood Pressure in Surgery."

‡ Howell, in "Festschrift for Victor Vaughan," 1904.

§ Butler, in Lancet, March 3d, 1906, vol. ii.

should be supplied by strychnia or other drugs. It will often happen, in spite of operative relief, if the patient come late to operation, that all efforts will be useless. If the blood pressure has fallen materially below 100 mm. of mercury and is still falling, it is very apt not to recover its tone, even though compression be relieved. Still there are remarkable results on record under such circumstances. Horsley, Rawling, Cushing, as well as others, have in several instances clearly saved life by a hurried operation. Kocher, speaking of the earlier stages of compression, deplores the practice of waiting until the general symptoms of bulbar compression become added to local signs before operating. The operation is less successful just in the measure in which such signs have appeared. Not only so, but not infrequently such signs appear a very short time before the development of the paralytic stage. He therefore lays down the general indication for operation thus: that in every case of cerebral lesion, especially traumatic, with signs of persisting and increasing severe disturbance of function, operation is indicated even where there are present none but the signs of focal injury; in other words, where there is no more than a suspicion of compression, we should trephine.

V. CONCUSSION OF THE BRAIN.

Definition.—Not many years ago it was a matter of no material difficulty to define exactly what was meant by concussion. The word signified, as indeed its derivation implied, a shaking together, a vibration of the brain as a whole, in such a way as to produce a "molecular disturbance," some indefinite rearrangement of the constituent molecules of the brain matter, quite invisible to the naked eye, or indeed to any means of examination within our reach. The cause was always a direct and considerable violence to the skull; and the effect, while it showed itself clinically in the universally known symptoms, was characterized at autopsy by the total absence of pathological evidence. On the other hand, if death did not ensue, the principal phenomenon was the rapid, or comparatively rapid, disappearance of all the symptoms. The essentials, therefore, were, on the clinical side, transitoriness of the symptoms, in that they ended either by quick death or by quick recovery; and, on the pathological side, the absence of visible pathological changes at autopsy, and their presumed absence in cases of rapid and complete recovery. Between these two extremes lay a large number of cases, in which either death came late, or recovery was slow with the persistence of signs pointing to brain lesion; and in which were found, if they came to autopsy, contusion or laceration with hemorrhage.

To-day, it may be said at the outset, this definition of concussion must be, at least in part, given up. "Vibration" of the brain itself does not occur upon the application of direct violence to the skull; "molecular disturbance" is a vague, unprovable thing—a mere juggling with words; and the lack of pathological evidence at post-mortem examination is now recognized to have depended upon lack of fine observation, that is, with the aid of the microscope. The proper place, however, for any exact definition, should be at the end of the chapter rather than at its beginning. If we first review the evidence, pathological and clinical, the summary may constitute the definition, so called.

The term concussion, or "commotion," as the French and Germans say, was used at the very beginning of written medicine by Hippocrates; and, later, by Galen and by Celsus; but it meant with them no more than the general fact of destruction, more or less terrible, of the brain substance. We find the same general meaning given to it in Ambroise Paré. Boirel (1677) seems to have been the first (I quote from von Bergmann) to modify this idea by calling attention to a group of lesions, in the domain of head injuries, which were caused neither by fracture of the skull nor by tearing of cerebral vessels, but were characterized by symptoms so transitory that any real damage to the brain was inconceivable. Later (1675), came Littré's celebrated autopsy-report upon the murderer who, contemplating a horrible death upon the wheel, himself "cut the thread" by running head on against the wall of his cell, straightway falling dead. At the post-mortem examination Littré found not the least trace either of fracture of the skull or of lesion in the brain.

Somewhat later appeared the doctrine of vibration, which has lasted without material change nearly to the present time. A blow upon the skull was believed to set the bone in vibration,—which, indeed, is true enough, though to but a slight degree; these vibrations were supposed to transmit themselves to the brain; the latter was so knocked about by this process that its constituent molecules were separated from their normal mutual relationships and suffered a rearrangement, the effect of which was to "atonize and paralyze dynamically" the nerve fibres and cells. Such a dislocation of molecules might be readjusted soon, late, or never. The last eventuality referred, of course, to cases which were promptly fatal; the dislocation of molecules had been so severe as to abolish all nervous function. This theory was held to explain satisfactorily both the transitoriness of the symptoms and the lack of evident pathological change, and it dominated surgical opinion during the latter half of the eighteenth century and the first half of the nineteenth. The "molecular disturbance" idea has even yet a strong hold upon the minds of many, even though their conception of it be, necessarily, sadly vague.

Already, however, in 1831, when Bright drew attention to the frequent occurrence of minute, discrete hemorrhages, "capillary apoplexies," in cases of concussion, doubt was being cast on the doctrine. Fano, in 1853, disproved the theory of vibration, and demonstrated on the contrary that, following a severe blow on the cranium, the movement imparted to the brain was that of a body propelled *in toto,* and that the brain was flung as a mass against the opposite side of the skull. He believed that concussion, as a lesion essentially different from contusion, was quite imaginary; as much so as the cerebral vibrations, whose existence he had disproved. Pirogoff and Beck believed that contusion was always superadded to concussion.

It is unnecessary in this place to go deeper into the historical aspect of the subject. What has been said has sufficed to indicate the great change of belief concerning the pathological nature of concussion which developed gradually during the middle of the last century. Since the seventies, a considerable number of experimental researches have been published, and these in the aggregate have set our physiological and pathological knowledge of the subject upon a fairly secure basis. Inasmuch as, however, the conception of concussion has always been much more definite on the clinical than on the pathological side, it will probably be best to begin with the symptomatology as generally accepted, and later proceed to inquire into its pathological physiology and its pathology in the endeavor to arrive at a full comprehension of the subject.

Symptoms.—As with other disturbances of the organism, it has long been recognized that concussion shows itself in varying grades of severity. Usually, in harmony with text-book exigencies, two grades have been established for the purposes of clinical description, the light and the severe. The case described by Gussenbauer is a good example of the moderately severe type, and has the advantage of having been seen from the first moment by a competent observer. Gussenbauer and a friend, while on a tour through the Alps, suffered a fall down the Eiger. The friend was rendered unconscious; Gussenbauer fortunately came to no harm. On rising (I quote from Kocher), he found his friend completely unconscious; the pupils were wide; the corneal and other reflexes were abolished; all the muscles were flaccid; the face was deathly pale; and a chance wound was not bleeding. He was not breathing, and looked quite lifeless. Evidently there was both cardiac and respiratory standstill. After a short while, there returned spontaneously signs of life: first the pulse, very weak and slow; then respiration, shallow and slow; then bleeding from the wound. Later, the reflexes reappeared; the man gradually began to hear; half-opened his eyes; and returned to a condition of semi-consciousness. After a while he fell into a sleep that lasted twenty-four hours; and it was only then that he regained full consciousness. A week later, all concussion symptoms had disappeared, save that he had lost all memory of the events immediately preceding the accident.

Cases of less severity than this are events familiar to all. The lightest are those which are compared to "seeing stars" with momentary giddiness and headache. If the blow be more severe, there supervenes unconsciousness, preceded by transitory dizziness, stars or flashes of light before the eyes, and a ringing in the ears. All the muscles become flaccid, and the victim falls in a heap. Usually the earlier signs observed in Gussenbauer's case, the standstill of heart and respiration, are not seen; they can, within the limits of possibility, be present only during the first moments, but it is rare for any one who would notice or record such things to be at hand. In the lighter cases, it is unlikely that the effect goes so far as to arrest pulse and respiration; in the severer ones, it probably does do so, but is rarely seen. Following this earliest stage, one finds the respiration so shallow as to be scarcely visible, and the pulse so small as to be hardly palpable; both are usually slowed to a marked degree. Such a condition in the lighter cases lasts but a short while. As one watches, the patient takes a deeper breath, the pulse grows under one's finger; he opens his eyes, and soon one can see in them the play of the senses returning; he may mutter something unintelligible, but soon complains of headache and ringing in the ears; stands up and tries to walk; his gait is unsteady; he is broken and feels very tired. All this passes off, and before long he is quite himself again.

The severer cases, resulting upon a severer injury, bear a general resemblance to the lighter ones; but the unconsciousness is more sudden, more profound, and more lasting. Days may pass before the patient comes to himself; and during that time he may react to no kind or degree of stimulus; all his reflexes are gone, save, usually, that of the pupil to light, and that of swallowing. These, like the bulbar centres, are automatic. Pallor of the face is extreme; the face looks sunken; the body temperature is low (94°–97° F.), the surface cool. Vital functions are greatly depressed; the pulse is small, apt to be irregular, and though occasionally rapid, is more often slow; breathing is fairly regular but very superficial, and blood pressure, as I find, is subnormal. Vomiting is frequent; there is either retention or incontinence of urine and fæces. The duration of the period varies from hours to days. If death ensue from concussion pure and simple, it must do so within a comparatively short time, the limit naturally not being a rigid one; but the longer death is delayed, the more likely is it to be due to compression or some other complication.

The return to the normal is usually gradual, and requires a longer or shorter time, according to the severity of the blow; pulse and breathing grow stronger; the face resumes its normal hue; the reflexes reappear; the patient becomes more and more conscious, and is finally clear in his head. Still, headache may persist and be severe for days, weeks, or even months. Before the patient returns to a completely normal condition, he frequently has to go through a reactionary stage of excitation, as if the pendulum were swinging too far in the opposite direction. This is characterized by a febrile condition, of which the ordinary signs are present, the pulse becoming somewhat rapid, blood pressure rising, fever and restlessness appearing, with pains over the whole body, but especially in the head. It is allowable to conjecture that this stage indicates the presence of lesions in the brain which go beyond pure concussion and into the domain of contusion, a condition which must be associated with a certain amount of hemorrhage and cerebral œdema. The symptoms are referable partly to compression, partly to the reabsorption of fibrin ferment from the effused blood. They last usually but a short while. What, however, it is essential to remember, what, indeed, is too often not remembered, is that if improvement does not appear with reasonable promptitude, and, *a fortiori*, if aggravation of symptoms supervene, we are no longer at liberty to rest our diagnosis at pure concussion, but must assume the presence of the more severe lesions of contusion or hemorrhage. Many a man has been allowed to die after a week or more of progressing symptoms under the vague and helpless diagnosis of "concussion,"—that is, an irremediable condition,—in whom the post-mortem examination has revealed a localized intradural or even extradural hemorrhage—a quite remediable condition.

We reserve for a later discussion the question as to where the dividing line between concussion and contusion is to be set. We have drawn the picture of the recovery cases of concussion, light and severe. There remain to be mentioned the quickly fatal cases, that is, those in which death ensues within a few minutes, a few hours, or, at most, a day. While the majority of these will show at autopsy extensive gross lesions of the brain, a few reveal either an apparently total lack of pathological change, or such slight changes (in the way of multiple minute contusions, capillary hemorrhages, and subpial extravasations) that the fatal issue can hardly be ascribed to their interference. Here death is plainly due to pure concussion, whatever the essential *modus operandi* of the latter may be.

Now, when we come to analyze the symptoms of concussion, we are able to extract certain underlying principles. As already said, the limits of concussion are best based upon clinical considerations primarily. We find, then, that the common factors in these cases are: *first*, that the symptoms are produced with extraordinary suddenness and with fullest intensity at the outset; *second*, that thereafter they diminish in intensity progressively, and are transitory, that is, disappear within a few days at the most. Any condition, therefore, which remains stationary for a long time, or which gets worse, is not pure concussion.

As to the symptoms themselves, we can reckon them summarily as consisting in disturbance of consciousness in varying degrees, together with alterations of the normal cardiac, respiratory, and blood-pressure functions. The former we refer to a lesion of the gray matter of the cortex as a whole; the latter to a derangement of the three vital centres in the medulla—the respiratory, the vagus or cardio-inhibitory, and the vasomotor. And we find in the histories of concussion cases the evidence of all grades of disturbance of these cerebral functions. The "flashes of light," "seeing stars," "seeing black," presumably indicate irritation or stimulation of the cortex; while absolute unconsciousness must represent its paralysis. The pulse is at one time quite absent, at another slow, at another rapid,—all of which point, in the majority of instances, to varying degrees of effect upon the vagus centre; the respiration is at a standstill, or is slow and shallow; the pulse tension is now weak, now strong,—evidences of stimulation or of paralysis of the respiratory and vasomotor centres.

What, then, are the changes of physiological and pathological nature that underlie these clinical phenomena? What is the scientific explanation of the phenomena of concussion? The endeavor to find an answer to these questions early led to experimentation. It would occupy too much space were we to recount in detail even the more important of the numerous researches upon this subject; so that we shall content ourselves with a résumé of the essential facts hitherto established, leaving aside the points still in controversy.

Pathological Anatomy.—It was at first believed, and still is by many, that, while concussion might be, and often was, complicated by the presence of very evident contusions, lacerations, and hemorrhages, to which the ultimate death of the patient was often due, there occurred frequently enough cases in which no discoverable lesion at all existed. Then came Bright, and later Rokitanski, with the demonstration of the frequent presence of minute capillary hemorrhages in cases of concussion. No real further advance was made until the modern methods of Golgi, Weigert, and Nissl in the examination of nerve tissue were published. With these there soon appeared the expected demonstration of minute microscopical degenerations of nerve and glia cells. Schmaus (*Münch. med. Woch.*, 1899) described them exhaustively in the human being; and also proved that, in the later course, secondary hemorrhages might occur in these areas of degeneration. Such was the mode of death in Bollinger's cases of "late apoplexy." Shortly before, there had appeared the articles of Bikeles (1895) and Scagliosi (1898), to which a more detailed reference will be made later. In 1895 Buedinger brought forth the same evidence on the human side. Examining the brain of a man who had died with severe concussion symptoms eighteen hours after an accident, he found numerous degenerated ganglion cells in the cortex and central gray matter around the ventricles.

We may therefore conclude that no case of concussion, save the very transient ones, is without its substratum of pathological lesion. In the lighter cases there are degenerative changes in the glia and nerve cells; in the more severe there is in addition widespread rupture of capillaries, with multiple minute hemorrhages. (Plate XXXIII, Fig. 2.*) As to the distribution of these, Ferrari's experiments (1882) showed that the capillary hemorrhages were most thick-set in the direct line of the violence; but that, corresponding to the spreading effect of the force transmitted to the brain, they were also to be found for some distance and in all directions outside this zone. In cases in which the skull did not break, the effect was apt to be most severe over the area of contrecoup contusion.

A third pathological condition sometimes found is represented by foci of

* See Kocher for more minute details (page 290 *et seq.*).

softening without hemorrhage, dependent on swelling and degeneration of the axis-cylinders and medullary sheaths. Hauser describes a case of this sort. (Hauser: *Deutsches Arch. f. klin. Med.*, Bd. 65.) The man died six days after receiving a blow upon the right anterior parietal region. In addition to contrecoup contusion, he found in the corpus striatum and thalamus foci of softening of a grayish-yellow color. Hauser remarks that if the brain had been examined on the first day instead of the sixth, no lesions would have been found, and the case would have been set down as one of fatal concussion without evident lesion.

While all these lesions in varying degrees must reasonably be considered to be the constant accompaniment of concussion, whether or no they represent its essential cause, we have now to consider whether the largest, though still small, areas of contusion with ecchymosis, either in the brain substance or in the ventricular walls (Duret), or on the surface, as are so frequently seen in the contrecoup area, are to be brought under the rubric of concussion or not. Kocher decides to include them—rightly, I think—inasmuch as the clinical picture in cases showing these lesions may be dominated from beginning to end by the symptoms of concussion; or, at least, the contusion symptoms may not appear till late. The class forms a transition between pure concussion and contusion; and its examples are numerous, both in experiment and clinically. Kocher proposes for it a combined name—contusion-concussion.

Such, briefly, is the pathological anatomy of concussion; and we may now turn to a consideration of its pathological physiology.

Physiological Effects of Concussion as Ascertained by Experimental Investigations.—The investigations of importance in this subject are those by Koch and Filehne, Duret, Horsley and Kramer, Polis, Maassland and Saltikoff (under Kocher's direction), and Cannon.*

We may premise, with Kocher, that as regards the immediate cause, concussion is always produced by the impact on the skull of a body in rapid movement, or of the skull in movement against a body. There must be a blow. The underlying idea, however, is that of suddenness of effect. A slow compression of the skull—as, for instance, when the wheel of a dray-cart passes over a man's head, or, as in a case lately observed, when the head is crushed between the buffers of a car—on account of the comparative slowness and the summation of the effect, lacks entirely the characteristic cortical and bulbar signs of concussion. Experimenters have sought to imitate this mode of action in various ways, which will be reviewed later; but their first object, a very necessary preliminary, was to find out what sort and what extent of movement was imparted

* Koch u. Filehne: Arch. f. klin. Chir., 1874, Bd. xvii., p. 190.—Duret: *Loc. cit.*—von Bergmann: *Loc. cit.*—Polis: Revue de Chirurgie, Paris, 1894.—Maassland and Saltikoff in Kocher's monograph, *loc. cit.*—Cannon, in Amer. Jour. of Physiol., vol. vi.—Kocher's presentation is very complete. See also Porter and Storey, in Amer. Jour. of Physiol., March, 1907.

to the brain by a heavy blow upon the intact skull. It has already been mentioned that the theoretical "vibration" of the cerebral mass was proved not to exist by Alquié, who, planting in the brain mass through a trephine hole a needle surmounted by a bit of paper, and then delivering a blow upon the skull, could not observe the slightest trace of a vibration of the needle. On the other hand, he saw the brain mass bulge up momentarily into the trephine opening, and sink back—a phenomenon which indicated clearly enough the fact of a sudden rise in cerebral pressure. Since Alquié's time this fact has been repeatedly demonstrated, and has been recorded graphically by Braquehaye (1894),* by Horsley, by Kramer, and by Cannon (1901), not to mention others.

It was evident also that the brain moved only as a whole, and, naturally, that it moved in the line of the violence, and away from it. Ferrari's experiments, at Kocher's suggestion, demonstrated this very clearly. Ferrari inserted small glass vessels containing a colored fluid into the brain at varying depths from the surface. Applying violence to the opposite side of the skull, he found that the glass vessels, if they were near enough to the surface, were broken by the impact of the brain against the skull wall. The depth beyond which they remained intact was 5 mm. Kocher has given a special name to this propulsion of the brain *in toto;* he calls it a throwing or flinging movement (*Schleuderbewegung*). As a matter of fact, experiments are hardly necessary to demonstrate to us the fact of this propulsive movement of the brain mass; every case of contrecoup contusion spells it to us with the greatest clearness.

There is one other effect, however, of a blow upon the skull that must receive consideration. As has been shown more fully in the section upon fractures, the skull is decidedly elastic. If a blow acting upon a limited area depress its normal convexity, and diminish thereby the diameter corresponding to the direction of violence, it is evident that by virtue of the skull's elasticity the diameters at right angles to the first must be increased,—a "zone of depression" and a "zone of bulging." There can be no absolute diminution of the available space so long as the skull does not suffer a depressed fracture; what occurs is simply a very rapid redistribution of the space. The brain, being incompressible and non-elastic, cannot follow this rapid redistribution. The diminution in one diameter must act upon it in the sense of squeezing or crushing. The only thing that can give way and make room, by its own recession, is the fluid content of the skull. And were it not for the internal and external water-beds furnished by the cerebro-spinal fluid with its escape toward the spinal canal, and were it not for the very free exit of the blood through the valveless cerebral veins, the brain substance would doubtless suffer much more from this squeezing effect than it does.

* Braquehaye: "De la Méthode graphique appliquée à l'Étude du Traumatisme cérébral." Thèse de Paris, 1895.

Duret, in 1878, formulated upon this basis his well-known theory, to the effect that the essential cause of concussion lay in this over-sudden displacement of the cerebro-spinal fluid from the lateral ventricles toward the spinal canal. Being forced under great and sudden pressure through the narrow aqueduct of Sylvius into the small space of the fourth ventricle, it overdistended the walls of these, and gave rise to multiple small lacerations and hemorrhages; these lesions formed the pathological basis of concussion. At the same time, as he believed, the impact of the fluid against the restiform bodies gave rise reflexly to a contraction of the cerebral vessels, and the general anæmia of the brain thus brought about was the sole and sufficient cause of the phenomena of concussion. This theory has long been disproved, in so far as it pretends to explain the whole matter, although the lesions Duret described undoubtedly occur at times, and may cause serious late effects.

Whether the cerebro-spinal fluid have little or much to do with the matter, there can be no doubt but that, as the result of the propulsion of the brain against the interior of the skull over a wide area, and also of the squeezing action mentioned, the blood is to a considerable extent mechanically expressed and the cerebral circulation temporarily interrupted. This explanation was propounded as a theory by Stromeyer many years ago; and, indeed, Kocher believes that the mildest grades of pure concussion are due to this factor alone, a temporary anæmia. It has been said that Alquié, Horsley, Kramer, and many others found that, upon delivering a blow upon the skull, there occurred a sharp rise of cerebral pressure; and the explanation of this we have just seen. A sudden space diminution in one diameter presses upon the cerebrum, and squeezes it into a trephine opening; upon cessation of the causative force, it sinks back. In view of this observation we must accept the dictum of Kocher, to the effect that concussion is an acute compression. Kocher urges the abandonment of the word concussion, because, etymologically, it implies "shaking" or "vibration," and would have us substitute the word "*Hirnpressung*" (brain-squeezing). The argument, while perfectly just, is hardly strong enough, in the writer's opinion, to justify the giving up of a term that has by long habitation made its citizenship so solid.

Having arrived, then, at the conception of concussion as in the main an acute compression, we should next inquire whether such a process can explain all the clinical phenomena of the condition, and, if so, how.

In 1874 was published the celebrated research of Koch and Filehne. All previous experimenters, using a single blow to cause concussion, had failed to accomplish this without producing simultaneous contusions and hemorrhages. It occurred to these authors to replace the single heavy blow of clinical experience by a series of light blows, from which they expected a cumulative action. These were directed at the rate of about two in the second against the side of the dog's head. In von Bergmann's words, "after a half to three-quarters of an hour of this 'hammering,' the animal's temperature had sunk two degrees, respiration had become slow and shallow, the pulse had fallen from 58 to 36; the animal lay perfectly flaccid and allowed its legs to be placed in any position, as if it were completely unconscious; it reacted to no painful stimuli; and autopsy revealed no macroscopical lesion in any part of the brain. By shortening or prolonging the period of hammering, they could produce apparently all grades of concussion, from which the animals either recovered quickly or went on to death. As to the behavior of the medullary centres, during the earlier stages, the respiration always increased rapidly in rate. (Polis, later, found it always slowed from the beginning.) The pulse became much slower, and the blood pressure rose; and, upon any interruption in the hammering, these all returned more or less promptly to near normal. But in the later stages, evidently of exhaustion, these various stimulus effects gave place to paralysis, in which respiration grew very slow and finally ceased, the pulse grew small and rapid, and the blood pressure fell to far below normal. Whereupon the animal died."

Through the authority of von Bergmann, these Koch-Filehne experiments were given an enormous importance in the explanation of the essence of concussion. He held them to be absolute proof of a *direct mechanical lesion* of the various parts of the brain that have to do with consciousness and the vegetative life—the cortex and the bulbar centres; nor only of these, but also of the brain as a whole; the effect was absolutely generalized. There was no question of any intermediary agency, such as reflex or mechanical circulatory disturbance. In 1895 Bikeles, and in 1898 Scagliosi, repeated these experiments in order to examine by modern and refined histological methods the brains of animals that showed no macroscopical evidences of the hammering. Both found extensive microscopical changes in all cases.

While these microscopical changes offer fairly good evidence of an actual mechanical effect upon nerve elements, and in so far may be accepted as a possible cause of concussion, the objections that may be urged to the acceptance of this series of experiments in general, as offering an explanation of concussion, are many. In the first place, the conditions of experiment were entirely different from those of the clinical occurrence. Instead of a single severe blow with sudden onset of symptoms in full intensity, we are offered a series of perhaps three or four thousand blows (if I understand it rightly) with a gradually increasing effect, a summation resembling to a large extent in its signs the development of compression, but largely mixed, unavoidably so, with a pure, reflex effect, which goes on, if pushed, into straight shock. Crile might have used the plan for one of his shock experiments. In addition, the symptoms produced do not correspond accurately with those of clinical concussion; the absence of sudden arrest of heart and respiration, and of the early fall of blood-pressure, or at least the transference of all these effects to the end of the experiment, are very different from what we see in the human being. It is well known that the stimulation, severe and prolonged, of sensory nerves is a sure way of causing shock, in which process the first effect is always a pressor one, with rise of blood pressure and increase in the respiratory rate. As the sensory stimulation is pushed, the pressor effect goes over into a depressor one, and there ensues a stage of paralysis of the vasomotor centre. This, a reflex paralysis by way of sensory nerves of the vasomotor centre, is the essential in shock. It appears to us that Koch and Filehne's experiments fulfilled these conditions much more exactly than those of concussion. Moreover, their records of respiration, pulse, and blood pressure resemble far more closely the course of an increasing compression, with its gradual slowing of pulse and respiration and steady rise of blood pressure, than that of concussion with its sudden standstill of pulse and respiration and fall of blood pressure. The tracing of Polis,* showing a Koch-Filehne hammering experiment lasting over an hour, is absolutely comparable with the ordinary tracing of a compression case. The natural supposition is that the hammering causes a progressive anæmia of the brain, which, if pushed, naturally induces paralysis of the bulbar centres and ends in a typical compression death. Whether this anæmia be caused by a direct effect on nerve cells, or by mechanical compression of vessels, or by filling of the splanchnic area through shock, or by all combined, are questions very difficult to resolve.

Duret's theory has been already referred to. It was based upon experiments which consisted in the main in forcing fluid suddenly under high pressure into the arachnoid space or the ventricles. On the other hand, the theory of a sudden reflex anæmia by impact on the corpora restiformia falls to the ground if we accept the present-day belief that the cerebral vessels are not supplied with vasomotor nerves. The capillary hemorrhages and small areas of softening which Duret found as a result in the walls of the fourth ventricle and the aqueduct of Sylvius have also been found not infrequently in the human subject in cases of concussion. Yet the idea that these lesions are a necessary accompaniment of the symptoms of concussion, as Duret claimed, has been long abandoned. Kocher showed, from Bollinger's cases of late apoplexy following concussion, that these same lesions in the fourth ventricle could be present as the result of a blow or fall on the head which had caused no loss of consciousness or evident bulbar signs. Moreover, Tilanus, Deucher, and also Polis were able to cause typical concussion after letting out all the cerebro-spinal fluid through an opening in the atlanto-occipital ligament. Finally, in Duret's original experiments, the symptoms could be immediately relieved by opening the atlanto-occipital ligament; which means that they were due to compression, not to concussion. The symptoms disappeared, but the lesions remained; therefore the lesions in themselves were not the cause of the concussion symptoms.

Horsley and Kramer's experiments are concerned only with the severer grades of concussion, as produced by a revolver-shot through the skull, with

* Polis. "Sur la Commotion Cérébrale." Rev. de Chir., 1894, vol. xiv., Fig. 6.

initial velocity of 200–300 metres. In their animals this caused immediately and always a sudden inspiratory cramp with complete cessation of breathing, which was frequently so long maintained that the animal died straightway unless artificial respiration were done. Parenthetically, it may be assumed that we have here the intimate cause of immediate death in the severest cases of concussion. Curiously enough, the author found cardiac activity to be frequently undisturbed; only at times was there at this early stage slowing of the pulse, indicating stimulation of the vagus. The blood pressure dropped very quickly at first. The authors demonstrated by direct measurement that the cause of the respiratory standstill was a very sudden rise in intracranial tension. Moreover, when they removed a large part of the cranial vault, and split the dura, the shot caused no standstill of respiration, and the brain matter was violently projected through the opening in the dura. It was reasonable to conclude that the respiratory phenomena were due to a direct effect on the medulla.

In 1894 Polis published an exhaustive investigation into experimental concussion. A single light blow caused inspiratory cramp, followed by accelerated respiration and a slight rise in blood pressure. A single severe blow caused standstill of the respiration, or at times only slowing; slowing of the pulse; momentary tetanic contraction of the muscles, followed by relaxation; and immediate loss of consciousness; also a rapid and decided rise in blood pressure, which, however, soon sank again to normal, even before the pulse became normal. The animal being killed in such a case, no lesion of the cerebral substance would be found, though a fracture and arachnoid hemorrhage might have occurred. If the animal recovered, blood pressure sank below normal, and the pulse grew faster. Polis notes also that where the blow was so severe as to crush the skull in pieces and destroy brain substance, the effects typical of concussion were frequently much less than when the skull remained intact. Kocher cites this in support of his belief that a sudden rise of pressure inside the unbroken cranium is the essential factor in concussion. Polis also repeated the "hammering" experiment of Koch and Filehne, and obtained practically the same results, with the exception that he could never by these means paralyze the vagus; even toward the end, cutting the vagus caused acceleration of the heart-beat, and stimulation of the peripheral end a slowing of the pulse. This is confirmed by late observations of Porter. He believed that the results of this "hammering" process were identical with that obtained by a single severe blow, and differed from the latter only in the degree of rapidity of action and intensity of effect; it was, in other words, true concussion. Only, for Polis, the condition of concussion, clinically understood, corresponded with the period of recovery from the hammering. In the two conditions there was parallelism of symptoms: complete unconsciousness, muscular relaxation, slow respiration, slow pulse, and fall of blood pressure. Reasons have already been given for not entirely accepting this view.

In a second part of his investigation, Polis demonstrated the very important relation between cerebral anæmia as cause, and the phenomena of concussion as effect. In a series of animals in which the brain had been rendered anæmic, either by general bleeding or by the ligature of the four chief cerebral arteries, carotids and vertebrals, he determined the effect of single blows and of the Koch-Filehne "hammering." In all, the symptoms of concussion appeared with surprising rapidity. In one rabbit, the hammering process induced within a few seconds, instead of the usual half to three-quarters of an hour, slowing of the respiration going on to a standstill, and slowing of the pulse also going on within six to eight minutes to standstill, and no fall of blood-pressure; indeed, in one case, a rise. At autopsy no lesion of brain substance was discoverable. In a dog the same effect was got; and in addition it was found that, while the peripheral blood pressure was high, 225 mm., that in the circle of Willis (distal end of the cut carotid) was down to 40 mm. as the result of the closure of the four chief arteries. A single severe blow during this condition of relative cerebral anæmia induced immediately standstill of the respiration and slowing of the pulse. He came to the general conclusion that the ease with which concussion was induced stood in direct ratio with the degree of cerebral anæmia present; moreover, that concussion during anæmia was very serious, and was apt to end fatally, a thing which was quite exceptional in animals with intact cerebral circulation. Finally, to complete the proof, he established the remarkable fact that by anæmia alone, without trauma (rapid alternation of closure and reopening of the cerebral circulation), it was possible to induce the typical symptoms of concussion.

Polis then calls attention to the clinical application of these facts in those cases of alcoholism, tumor, hydrocephalus, and others characterized by intracranial tension and disturbed cerebral circulation, in which a very light blow may be sufficient to cause severe concussion. Thus he warns against the use of hammer and chisel in doing a craniotomy in such cases. With regard to fatal concussion, these anæmia experiments show that the violence necessary to cause death varies with the degree of vascularization of the brain, and prove the fact that the concussion of a light blow may be fatal without the presence of lesions of the brain substance. The medico-legal application is obvious.

A third very important experimental investigation of concussion was that carried out by Maassland and Saltikoff under Kocher's direction in Berne. Their method of inducing concussion consisted in suddenly applying larger or smaller weights upon a steel cylinder which rested directly upon the dura mater through a trephine opening. The shock which the brain thus received gave rise to typical concussion symptoms. Kocher considers, in his account of them, chiefly, or only, the bulba reffects. It seems reasonable to accept this mode of experiment as reproducing closely enough the clinical event, save that in most instances the weight was left applied, that is, the initial violence of the force was continued for a length of time that is not seen clinically, up to twenty-eight seconds; and in the next place, that the method imitated very imperfectly the throwing or flinging movement imparted to the brain. The contrecoup effect, therefore, must be largely lacking. Naturally, the results differed more or less according to the weight applied—that is, the violence of the blow. The effects upon respiration, heart action, and blood pressure were, in brief, as follows: With the sudden application of a moderate weight, representing the effect of a blow of moderate violence, there occurred usually immediate standstill of respiration, lasting often for as much as twenty seconds, but then recovering spontaneously. With this there could be seen also the evidence of stimulation of the vagus in a somewhat slowed pulse, although this might not appear if the violence were slight. This slow vagus pulse with its big excursions was apt to last for some time after the respiration had returned to normal. The blood pressure immediately after the violence usually fell slightly during respiratory cessation, but would rapidly recover, and might rise a little above normal. If the weight were heavier and the violence presumably of moderate severity, the effects were more pronounced. In addition to respiratory cessation, there was apt to occur cardiac standstill. Both these phenomena were found, definitely enough, to be irritation or inhibition effects. The immediate fall in blood pressure was more marked; this, as Kocher shows, was not due to a paralysis of the vasomotor centre itself, but was secondary to the standstill of pulse and respiration, a purely mechanical result of the interference with cardiac action. This primary fall was, however, very soon replaced by a rise, due in part to sensory nerve stimulation, in part also, doubtless, to the temporary bulbar anæmia of asphyxia, which acts by stimulating the vasomotor centre. The heart within a few seconds resumed its beat, and there appeared a marked vagus pulse apt to continue for some time. With the resumption of the heart-beat and the rise of blood pressure the respiration recovered, although it might remain shallow and slightly disordered in rhythm for a while.

If finally the weight applied were considerable (4 or 5 kg.—9 to 11 lbs.), representing a very severe violence, the effect on the bulbar centres took on, to some extent, a paralyzing nature. Respiration stood still, but after removal of the weight, especially where it had been left on longer than usual, *e.g.*, twenty-eight seconds, its recovery was introduced by a period of very superficial and irregular breathing; in some cases there was no attempt at recovery. Likewise with the vagus centre, instead of the inhibitory irritation effect, there would appear immediately the rapid, small pulse of paralysis of the vagus, which might or might not recover upon removal of the weight. The blood pressure would first sink, for the reason before mentioned; then rise, as the expression of the irritation of the vasomotor centre by bulbar anæmia; finally, but still within a few moments, it would fall gradually again to or below normal. If, however, the violence were too great, not only would the respiratory and vagus centres, but also the vasomotor centre, be paralyzed, with rapid and irrecoverable fall of blood pressure.

Kramer, in a smaller series of experiments, obtained very similar results, which we need hardly repeat here.

W. B. Cannon's research was chiefly concerned with the development of cerebral œdema after the trauma of concussion; but his observations upon the bulbar effects agree closely with those already related. The immediate result of a blow upon the animal's head with a hammer was an enormous increase of intracranial tension. This was only momentary, but checked for a few moments the flow of blood into the brain. The respiratory centre might be paralyzed for a time and recover. General blood pressure rose slightly at the moment of the blow, but then fell markedly, and the return to normal was gradual. He concurs in the general belief that the primary unconsciousness, clinically, is due to the anæmia resulting from the checked flow of blood and the fall in arterial pressure.

When we resume all these experimental investigations, we find that, so far as the effect of concussion on the bulbar centres is concerned, the factors common to all are these: in slight concussion, a transitory disturbance of respiration without effect on the vagus or on blood pressure; in moderate concussion, inspiratory cramp, followed by a rise of blood pressure and a vagus pulse, due mostly, no doubt, to the anæmia of the bulb resulting from the temporary asphyxia; both of these lasting but a short while, and followed by a fall of blood pressure to or below normal, and a more gradual restoration of a normal pulse; in severe concussion, standstill both of respiration and of heart from over-stimulation of the respiratory and vagus centres, with marked fall of blood-pressure, followed by slow restoration to normal; if very severe, paralysis of all these centres, leading to total cessation of breathing, a rapid pulse, and a swift fall of blood pressure to zero, and so to death.

The Correlation of Physiological with Clinical Phenomena.—These considerations drawn from animal experiment we find to be abundantly confirmed by clinical experience. If the reader will go over again the account of Gussenbauer's case (page 147), he will easily see how great is the parallelism. As to the bulbar effects: first, the preliminary stage, showing standstill both of respiration and of pulse, representing undoubtedly the extreme of stimulation, with consequent inhibition, of the respiratory and cardio-inhibitory or vagus centres. No pulse could be felt, and the wound did not bleed. Then within a few moments the partial recovery, with slow, weak, irregular pulse and slow, shallow, irregular respiration. In Polis's case, seen four or five minutes after the accident, respirations were 4 or 5 to the minute, and pulse 48, both very irregular. This lasted about twenty minutes; and consciousness returned only after fifteen hours. In analyzing our hospital case reports, it has been easy to observe the same parallelism with the data of animal experiment. In mild cases with a short period of unconsciousness one finds the respiration noted as "regular" and "normal," the pulse as "regular" and "of good tension." In a severer case the respiration was "shallow and rapid, 36 to 44 in the minute," but came down within twenty-four hours to 20 to 24; the pulse (about one hour after the accident) was "scarcely to be felt; its rate about 84; it then became very irregular, rate from 90 to 104, but of better volume; and in twenty-four hours it was normal." In a very severe case which ended fatally within two hours after the accident, the respiration was shallow and gasping, rate 4 to the minute; the pulse was 150, and weak—clear evidences of paralysis of all the bulbar centres. On the clinical side, however, we lack exact information of the blood pressure. The employment of the sphygmomanometer in these head injuries is still so infrequent in hospitals that but little information on the question is available. Of course, in the first half-hour or hour, while the patient is being brought in on the ambulance, it is hardly possible to do this; although this difficulty would by no means be insurmountable to a keen house-surgeon with the help of the latest modifications of the Riva-Rocci instrument or Leonard Hill's new portable one. Of the later course, however, the writer possesses a few records. At this stage we find, in consonance with the tracings of experiments, a subnormal blood pressure as low as 88 mm. Hg, which may need from twelve to twenty-four hours to get up to normal. As to the matter of unconsciousness, which we are accustomed to think of, perhaps wrongly, as being the immediate result of interference with the cortex as a whole, the parallel is certainly maintained as far as the first hour or two are concerned, which is as long as an animal experiment lasts. But in the human being, what always impresses one is the length of time that it takes to disappear. It is true that in some experiments, such as those causing severe anæmia of the cerebrum through ligature of vessels going to the brain (Leonard Hill, Polis), the animals remained sometimes for as much as fifteen hours in a state of semi-consciousness. Yet such an argument is rather a begging of the question, and the unconsciousness lasting for days, as we occasionally see it in the human being in instances where, from the absence of compression symptoms, we are obliged to suppose the presence of concussion alone, is not observed in animals so far as I know.

Pathogenesis.—In considering the pathogenesis of concussion, certain problems stand out prominently. *First*: What is the cause of the sudden initial unconsciousness and of the interference with the respiratory, vagus, and vasomotor centres? Is it anæmia alone (Kocher); or "ébranlement" (shaking) alone (Koch-Filehne); or the two combined (Polis); or shock (Fischer)? *Second:* What is the cause of the persistence for hours or days of these same symptoms? *Third.* What is the cause of their subsequent complete disappearance? In endeavoring to bring answers to these questions, I shall review briefly the theories of the authors mentioned, and at the same time discuss them generally.

The theory of Fischer was to the effect that a blow upon the head induced, through the vasomotor centre, a reflex paralysis of the arterial musculature, upon which followed immediately a compensatory venous engorgement. The heart, slowed both reflexly and also directly by the overfilling of the veins, was unable to overcome the slowing of the circulation, and this condition abolished the nutrition of the nervous elements; hence the disturbances of consciousness and of respiratory and vagal action characteristic of concussion. In short, concussion was simply shock, and its symptoms were due wholly to vascular and nutritional derangement. In mild cases it was supposed that only the cerebral vessels were paralyzed; in severe, that the paralysis affected the whole arterial system.

Relation of Concussion to Shock.—This theory has gained a new interest from the late work, principally of Crile, and also of Howell, upon surgical shock. The trouble is to determine and to be agreed upon the definition of shock. Physiologists are not yet entirely at one upon the matter, nor are clinicians; for it is, after all, a vague term. If, however, we accept the conception which defines shock as a condition (quoting Howell) that "is characterized by long-continued low arterial pressure ('vascular' shock) due to partial or complete loss of activity of the vaso-constrictor centre, and by a rapid, feeble heart-beat ('cardiac' shock) due, in part at least, to a partial or complete loss of activity of the vagus centre," and in which also "the respirations are diminished in amplitude and usually in rate," we arrive at a possible basis of comparison. We must add, too, that in this definition the etiology is included as an essential part, to wit, that the depression is caused by long-continued stimulation of the sensory nervous system. In concussion we have certainly the same lowered blood-pressure and the same diminution of respiration; but the heart-beat, while feeble, is frequently not rapid. The striking difference, however, lies in the matter of disturbance of consciousness. In shock, the patient is usually conscious, unless in the moment of death; in concussion, he is not. The difference, of course, takes origin in the manner of causation: in the one, reflex depression of vital centres by over-stimulation of sensory nerves; in the other, a direct mechanical injury to the cerebrum itself; in the one, the development is comparatively slow; in the other, it is lightning-like in its suddenness.

Howell finds that operations on the brain are one of the most certain ways of inducing shock; and clinical experience confirms the idea, although Polis claimed that he could curette out the major part of the cerebrum without causing material change in the action of the medullary centres. Why it should be so, is difficult to understand upon the accepted theory that shock is caused by overstimulation of sensory nerves, for we know now that operations may be conducted on the brain substance without pain, under a local anæsthesia that extends only to the dura.* I imagine that in such cases, hemorrhage, even

*J. F. Mitchell: "Local Anæsthesia in General Surgery." Journal Amer. Med. Assoc., Aug. 20th, 1907.—Thomas and Cushing: "Removal of a Subcortical Cystic Tumor at a Second Stage Operation without Anæsthesia." Jour. Amer. Med. Assoc., March 14th, 1908.

slight, affects the intracranial circulation more than we think, and that a loss of blood in this region may cause shock or collapse effects quite disproportionate to the amount lost.

All this is very different, however, from that peculiar method of damaging the brain that obtains in concussion, that flinging movement of the brain against one side of its rigid case, with the very sudden space diminution and consequent brain-squeezing which that implies. Upon the whole, I believe we are hardly justified in regarding the consequent clinical condition as one of shock, unless we widen our definition of shock to admit it. Although, in the effect upon the bulbar centres, the two are very much alike, they differ absolutely in their etiology.

Koch and Filehne ascribed all the phenomena of concussion in their experiments to the direct mechanical effect of the violence on cerebral centres, and denied all participation in the result to the vascular system.* In what manner the concussion was transmitted to the nervous centres they did not say, whether by oscillation or by a movement in mass. The prolongation of unconsciousness, and of bulb symptoms, might be due, they thought, to the accompanying anæmia, but this was purely secondary.

In the opinion of Polis, both the purely reflex vascular theory of Fischer and the purely mechanical theory of Koch and Filehne were equally erroneous, because too exclusive. His own experiment, which showed the possibility of causing the phenomena of concussion merely by cutting off and letting on the blood current in frequent alternations, spoke too strongly against the latter. On the other hand, the theory of pure anæmia failed to explain the extraordinary suddenness in onset of the concussion symptoms of a severe head traumatism. In the opinion of Polis, both anæmia and direct "shaking" (ébranlement) of the cerebral mass were necessary. The classical experiments of Kussmaul and Tenner, together with the later ones of Bastgen, Markwald, and of Couty (embolizing of the cerebral vessels with powders and emulsions), all induced dyspnœa as the result of the sudden anæmia, sometimes going on to convulsions. In concussion, on the other hand, one got nothing but respiratory standstill. There was here a great lack of correspondence; it was evident that sudden anæmia alone was insufficient to account for the brusque respiratory cessation.

There was, therefore, need of the assumption of a direct mechanical disturbance of the brain. Further, Polis asked why, in certain cases, the respiratory centre recovers spontaneously, in others only with the help of artificial respiration; and in still others not at all. Likewise, with the other bulbar centres, why is there in the one case stimulation of the vagus, in the other paralysis? All this, he concludes, can be explained only by admitting the intervention of both factors. As a further argument, he recalled the observation of Gussenbauer in

* "Das souveräne Characteristicum der Commotion bleibt die für jedes Centrum auf directem Wege eingeleitete Functionsabschwächung, resp. Functionsaufhebung."

respect of the permanent loss of memory pictures, dating from shortly before the accident; a fact which was irreconcilable with the theory of pure anæmia. Further, Polis believed he had shown that this anæmia was not due to any reflex contraction of the vessels through the vasomotor centre (Duret, Fischer, etc.), but to an action of the violence upon the vessel walls directly.

Kocher has written at considerable length upon concussion. His theory of the pathogenesis rests upon two bases: First. That of a transient anæmia of the cerebral vessels, the cause of which resides in the mechanical effect of pressure of the skull upon the brain and, contrariwise, of the brain upon the skull during the immediate acute rise of cerebral pressure following on the blow. This can explain only the lighter cases. Second. That of widespread microscopic contusions, the size of which ascends in the scale to quite respectable proportions. These are the result of two movements imparted to the brain by a blow upon an elastic skull: (*a*) The movement *in toto* of propulsion or flinging (*Schleuderbewegung*). The impact of the skull against the brain, and that of the brain against the skull at the area of contrecoup, cause mechanical lesions by direct violence. (*b*) The internal movement, by virtue of the sudden change in shape. This results in an internal rearrangement of the constituent parts of the cerebral mass. It means an extensive distortion of the network of glia and neurons, with their cells and vessels. The resulting lesions are diffuse microscopical contusions. But these may be also macroscopical, with hemorrhages of varying size. One may even find large tears and bruises, by driving of parts of the brain against the resistant falx, or by the mutual opposition of different parts of the brain owning a different specific gravity or a different density of structure (Tilmann). All these lesions, provided they do not cause gross focal signs, Kocher reckons under the rubric of concussion; and he indicates, quite rightly, that it is more or less idle to discuss where concussion ends and contusion begins. The *modus operandi* is really the old "tassement" of Littré, a word which indicates that "piling up" of the force inherent in a swiftly moving body when it strikes an immovable object, and which causes the body to "double up" on itself. These lesions he seems to assume to be the real cause of the cortical and bulbar signs that last beyond the transient anæmia of the initial acute compression. "So soon as the violence of the blow goes beyond the mere emptying of the vessels, with consequent momentary anæmia and secondary hyperæmia, and injures mechanically the nerve substance itself even in the slightest degree, there appear symptoms indicating more lasting cessation of function; thus, complete unconsciousness with the disappearance of all sensory or motor impulses where the cortex is extensively involved; further, with contusions in the region of the medulla, interruption of breathing and irregular rapid pulse, that is, symptoms of paralysis in the place of those of irritation or pure inhibition." (*Loc cit.*, p. 339.)

Such is, briefly, the theory of Kocher: that concussion is in its essence an acute compression of the brain, a squeezing or pinching, the results of which are, first, a momentary anæmia, and, second, multiple, diffuse microscopic contusions; and that the clinical phenomena of concussion are best explained by these two factors.

To return to our first problem, the cause of the initial unconsciousness and of the varying effect upon the medullary centres, it seems to me that the arguments of Polis are valid, and that these symptoms must be due to a combination of mechanical (ébranlement) and vascular (anæmia) disturbance. The trouble, however, is to get any clear idea of just how this "ébranlement" acts upon the nerve tissue which has charge of the functions mentioned. The word and the idea are vague. And the transitoriness of concussion symptoms accords ill with any idea of mechanical interference with nerve conduction or perception, which is so apt to be long-persisting.

Coming to the second problem, the cause of the persistence of the symptoms for hours or days after the disappearance of the initial cause, Kocher, so far as I find, is the only one to discuss this question. The chief objection I would make to his theory is that the cortical and bulbar symptoms cannot possibly be dependent on actual lesion of nerve tissue, for the one reason that they are transitory, and disappear within, at the most, a few days. The very symptom to which Kocher most strongly appeals as proving the focal pathological character of concussion—viz., the loss of memory-pictures of the time just preceding the accident—this very symptom is apt to be permanent or long-standing. By analogy, the unconsciousness and the respiratory and vagal disturbances ought to be long-standing or permanent; which is not the case.

Now, if we analyze the chart of even an ordinarily severe case of concussion, we find that the unconsciousness lasts a day or two, and that the bulbar effects —slow, or occasionally rapid, respiration and pulse, but, both of them, above all, irregular in rhythm, depth, and volume, with a subnormal blood pressure—while usually disappearing before the unconsciousness, also take frequently from twelve to twenty-four hours to vanish. If we refuse to accept Kocher's explanation of multiple contusions, we have to ask whether these effects, so long persisting, can be due to a transitory anæmia. Or is the anæmia really not transitory? Does it continue relatively insufficient for a day or two, as the expression of the lowered blood pressure? But if so, what is the intimate cause of the persisting low blood pressure, as well as of the interference with the two other vital centres? Is it shock as we understand the word to-day? Or is it a mechanical effect upon nerve-fibres and cells?

I suppose that we may define consciousness, taking it at its lowest level, as the sum total of our perception and re-presentation of incoming impulses, chiefly sensory—the expression of the "*vie de rélation.*" We are accustomed to think of the "organ" of consciousness as being resident in the gray matter of the cerebral cortex as a whole, and not in any one part of it. No limited lesion of the cortex is able to induce unconsciousness; whereas even a partial anæmia, if it affect the brain generally (as in syncope), brings on a loss of consciousness with the greatest regularity. It is to be premised, also, that the integrity of the bulk of the afferent fibres leading to the cortical cells, and of the association fibres, is necessary to consciousness. It is evident, therefore, that, when concussion causes unconsciousness, it must do so by a widespread interference with the cells of the cortical gray matter generally and also, possibly, with a large number of the ingoing fibres as well as the various association fibres. That anæmia is present and causative cannot be denied. Besides the great mass of inferential proof, Cushing saw it directly through a window in the skull at the moment when a sudden and forcible injection of salt solution into the intradural space called forth concussion symptoms. The only question is how to account for the persistence of unconsciousness and of bulbar disturbances over many hours, long after the anæmia of the first sudden brain compression produced by the blow has presumably passed off. That it can hardly be due to a continuance of any complete anæmia may be concluded from the fact that any such condition would soon drive the blood pressure up above normal, as we know from Hill's and Cushing's work on compression; whereas the blood pressure recovers but slowly. The vasomotor centre is clearly in a state of depression, and to this extent the condition is analogous with shock. The fleeting, first stage of inhibition, inducing standstill of respiration, and of the heart by excess of stimulation, or, in the most severe cases, immediate paralysis of both respiratory and vagus centres, is generally ascribed to a reflex effect and called shock. The vasomotor centre, the most resistant of the three, escapes in this stage if the violence be slight, but its tone is depressed, and blood pressure is lowered in a degree which seems to run parallel with the degree of violence; and this not at all as a result secondary to the paralysis of the other two centres. Whatever the cause of the depression of the three chief bulbar centres, it is a cause that acts independently and similarly on all three. That this cause is a direct mechanical interference with the ganglionic cells which compose these centres, in the way of stretching or breaking or compression, or with the fibres going to and from them, leading to multiple contusions, we have already given reasons to disbelieve. Such lesions are present, but they are by-products, as it were. Whether it is a purely functional effect, physiological rather than anatomical, of the nature of an overstimulation by way of sensory nerves, and therefore in a sense one of the phenomena of shock, it seems impossible at this time to say. The primary immediate unconsciousness is without doubt due to the fleeting compression of the violence, the "*compression passagère*" of Stromeyer, together with the cardiac standstill. But what of the subsequent prolonged unconsciousness lasting hours and days? It seems to me too difficult to accept the idea that it is due to a destruction of nerve elements. Such a result would needs be permanent except in so far as compensation may develop; and compensation of nerve lesions is always tardy. I believe that the proximate cause of the persistence of unconsciousness is a condition of partial anæmia of the cerebrum, due to the marked depression of vasomotor tone, and also, though to a less degree, of respiration. The result is an inadequate supply of insufficiently aërated blood to the brain. Clinically, we see its effect in all grades, from mere sleepiness, the "sleepy stage" of Jonathan Hutchinson, to deep unconsciousness. With the rise of blood pressure and the restoration of the respiratory and vagus centres to their normal action, which needs from twelve to twenty-four hours, the unconsciousness gradually disappears. According to the severity of the injury and the depression of the vital centres, so is the grade of anæmia, and so the rate of restoration of consciousness. There are, however, certain other causes of this partial anæmia—cerebral œdema and capillary thromboses.

The observations of Cannon have demonstrated the more or less constant development of œdema as the result of severe concussion. This, he believes, requires some time for its development; in the cases quoted, it seems to have been sufficiently marked by the second day to cause definite pressure symptoms (bulbar and motor). It seems to me very probable, from the analogy of meningeal serous effusions, that such œdema develops within the first few hours in quantity sufficient to promote unconsciousness or semi-consciousness by local cerebral pressure, without reaching at that early stage the degree necessary to call forth the bulbar effects of generalized compression, or those of local compression such as motor paralyses. The cortical function is always affected before the bulbar functions. It seems reasonable also to think that the numerous widespread thromboses in the capillaries of the cortex, which are the natural and almost immediate effect of the diffuse violence of concussion, may, until a good collateral capillary circulation is established, assist in prolonging unconsciousness by virtue of the partial anæmia they must cause.

Under the terms of this theory, the prolonged unconsciousness of concussion, as opposed to the instantaneous primary loss of consciousness, would be due to the persistence of a partial anæmia, itself the result of an almost immediate interference with the capillary supply by minute thromboses, and succeeded by the rapid development of intracerebral, or more especially of intracortical, œdema sufficient to induce considerable cerebral pressure. Associated with this would be the loss of vasomotor tone already referred to; and the possibility of a vicious circle in the maintenance of the partial anæmia is at once evident. As to the third problem we may say that, with the restoration of nutrition in the cortical cells, with the slow recovery of lowered blood-pressure, and with the natural subsidence of the œdema, the unconsciousness gradually disappears. In any case, if we are going to include in our conception of concussion the transitoriness of the lesion, it seems necessary to postulate a cause which also is transitory; and to my mind, an anæmia of varying grade, affecting the cerebral cortex, would most naturally answer this requirement. Such permanent effects as loss of memory-pictures, nystagmus, stuttering, middle-ear and labyrinthine lesions; such as dizziness, subjective noises, loss of perfect equilibrium, and certain disturbances of hearing (Rhese, *Deut. med. Woch.*, April 19th, 1906); psychic disturbances; even such effects as suggest concrete nerve lesions in the medulla, such as long-persisting tachycardia; and, finally, that obscure lesion of nerve cells which results somehow in the development of diabetes,—each of which is only occasionally observed,—we may include under concussion, with the understanding that they probably represent small localized destructions of nerve tissue, and as such occupy the border-line toward contusion. But they are indirect effects of concussion; they are present also in cerebral lesions in which concussion has played no part, and therefore do not belong to the essential symptom-complex of concussion.

Prognosis.—If, in what precedes, the purely physiological work upon concussion has been reviewed at some length, it has been under the conviction that in no other way is it possible to obtain an insight into the intimate nature of the process, to comprehend its symptoms or, consequently, to deliver a reasoned forecast, or to treat the patient intelligently. The immediate prognosis concerns the patient's chances of life; the ultimate prognosis, his chances of functional recovery. As to the former, we must accustom ourselves to reason in physiological terms. The damage done is to the brain as a whole. But with regard to the chances of life, the damage done is to the medullary centres. These maintain the vegetative life. The "life of relation," governed by the cerebrum mainly, is also damaged; but we need not give much thought to it; mere unconsciousness is not dangerous, nor is its depth necessarily a measure of danger. The danger lies in the degree to which the respiratory, vagal, and vasomotor centres are affected; more than all, the vasomotor. These we must learn to scrutinize carefully and with understanding. Let us suppose a moderately severe case of concussion. It is necessary to examine closely into the work of each centre, to watch it for some time; and then to translate the findings into terms of stimulation, depression, or paralysis of the centre. The result will give the prognosis *quoad vitam*. It goes without saying that skill in such interpretation will depend, just as does purely clinical knowledge, upon experience. A thorough basis of physiological knowledge gives one a very long start on the road of clinical experience.

The reader will have observed that a great difference between the three vital centres in their resistance to concussion stood out most clearly in the experiments. The respiratory centre is the least resistant, the soonest to answer to the irritating effect of direct pressure with an inhibition-standstill; the vagus centre is more resistant than the respiratory, but less so than the vasomotor centre. The latter is the last to be directly influenced by pressure. Its irritation, in the words of Kocher, appears at a time when cessation of function on the part of the other two is already present. Its great power of resistance saves the patient's life even after extremely severe concussion, just as it does in cases of increasing compression. Where concussion is only severe enough to cause irritation symptoms on the part of the respiratory and vagal centres, the vasomotor centre is usually unaffected; and its calm continuance of action favors the easy recovery of the other two. If the latter are actually paralyzed—no longer merely irritated—by over-great shock, the vasomotor centre may still save the situation, in spite of the transitory primary fall of blood pressure, provided it be still able to respond to stimulus (bulbar anæmia and drugs) and drive up blood pressure. Its paralysis, however, with consequent permanent fall of blood pressure, is the signal for a fatal issue. It is thus easily seen how extremely important in concussion, as in compression, is a record of blood pressure as well for prognosis as for treatment. A falling blood pressure is a distinct warning of an unfavorable issue; on the other hand, a pressure which, though subnormal, remains stationary, or which, *a fortiori*, shows steady rise toward the normal, means, other things being equal, a good prognosis.

It is the vasomotor centre that gives earliest and surest warning. If the case end fatally, it is not really a primary failure of respiration, though the heart may continue beating for several minutes after complete cessation of breathing. As in compression, so in concussion, and so also in many infections even,* the primary failure lies in the tone of the peripheral vessels; in other words, in the tone of the vasomotor centre, and not in the heart or the respiration. I have already, in the section on Compression, expressed my conviction that the practitioner should own and use blood-pressure instruments, as he uses other instruments of precision, such as the laryngoscope and the ophthalmoscope.

If the patient is unconscious, but respiration and cardiac action are approximately normal, there is no immediate danger. At the other extreme lie those cases which, only exceptionally seen by the medical man within a few minutes after the accident, are found with bulbar centres apparently paralyzed, or else overstimulated to the point of permanent inhibition, respiration abolished, and pulse impalpable. These are fatal at the moment, unless artificial respiration avail.

Between these two extremes lie all degrees of affection of the bulbar centres, so that specific statements can hardly be made. In a general way, however, it may be said that if the blood pressure persistently measure much below 100 mm. Hg in the adult, especially if the respiration be shallow and slow, there is danger. The rate of the pulse is not so valuable as an indication, because it is regulated by other influences than the vagus centre, and is subject to independent variations. It may be rapid, but not infrequently in my experience it is very little above normal, 80–100; and occasionally it is very slow, without

* See Janeway, New York Med. Jour., February 2d, 1907: "Some Common Misconceptions in the Pathological Physiology of the Circulation," etc.

coincidence of compression signs. In quite severe cases I have found the rate to be not far from normal, but in rhythm and force markedly irregular and weak. A very rapid pulse points to vagal paralysis from great violence, and, if respiratory and blood-tension symptoms correspond, is of dangerous import. The respiration in cases of moderate severity going on to recovery I have found often accelerated. Thus in one case it was 36–44 at first, and came down gradually to normal only after twenty-four hours. At the same time, the pulse was very small and weak, and only 84 in rate at first, soon becoming very irregular; but in twenty-four hours it too was normal. A slow, shallow respiration is more serious. In one patient who died in from one to two hours after a fall upon the head, the respiration was 4 to the minute, shallow and gasping, while, the pulse was 150 and weak—plain evidences of respiratory and vagal paralysis.

The march of symptoms is certainly more important than isolated observations. A respiration becoming slower, a pulse becoming quicker, and, above all, a blood pressure falling indicate approaching exitus.

Unfortunately, clinical work in blood pressure is of such late date that I have not been able to procure any continuous observations on very severe cases of concussion. In this respect we must be guided by the physiological evidence; yet I have not the least doubt that confirmation on the clinical side will very soon be forthcoming.

It is hardly necessary to say that the ordinary clinical signs also show aggravation in very severe cases. Thus the temperature is, and remains, subnormal (1°–3° F.); the unconsciousness deepens; the pallor of the face and coldness of the extremities increase; and so with other regular signs of impending dissolution.

Remote Prognosis.—The remote sequelæ of concussion and of other head injuries, consisting in various emotional and mental effects, will be considered together in a special section (page 285 *et seq.*).

Modes of Death in Concussion.—Both through experiment and by the observation of one or two clinical cases (Horsley), seen very soon after the accident, we know that death may occur by the pure persistence of the initial respiratory cessation caused by the blow. Such, doubtless, is the inherent cause of every immediate death by concussion. This mode is, however, exceptional. In the majority of the very severe cases, the subjects die after the lapse of a few hours, presenting in the main the symptoms of severe progressive shock. Their vital centres are greatly depressed at the start; restorative measures seem to do no good; and the blood pressure goes on falling, until an irrecoverable condition is reached (experimentally, according to Crile, 20 mm. Hg); it is progressive depression, the nature of which we do not yet understand. It is a question how far concussion is responsible for the death that occurs, say, over a day after the accident. The longer the issue is delayed, the more likely is it that other factors come into play, compression most often. The boundary line is very indefinite.

Treatment.—In the consideration of treatment, I would like to establish three groups of cases: those that die in the first few minutes; those that die in a few hours or a day or two; and those that recover.

1st. For the immediate paralysis or, perhaps, inhibition of respiration which threatens to be so prolonged as to cause death, there is only one thing—artificial respiration; a measure likely to succeed, at least for the time being. Horsley has emphasized the value of the procedure, and has advised also the use of hot douches to the head. Cardiac standstill also occurs from overstimulation of the vagus, but the same measure is the remedy for this also; artificial respiration is our best and readiest means of raising blood pressure, in the presence of respiratory paralysis.

2d. In those severe cases, both clinical and experimental, in which death supervenes, not within a few minutes, but within a few hours, the cause of death is chiefly the direct paralyzing effect of the violence upon the vasomotor centre, whether by prolonged anæmia or by "ébranlement," and also in a subsidiary way upon the vagus and the respiratory centres. The fall of blood pressure is here progressive and more or less rapid; and if it go beyond a certain degree (in animals from 20–40 mm. Hg), its recovery by artificial respiration or any other means known, is, in experiments, impossible. Clinically the same must hold true. We can, however, never know at the moment whether the vasomotor centre is irremediably paralyzed or not; so that our duty is always to employ all possible means to restore blood pressure. Indeed, Porter has lately demonstrated that, in conditions of experimental concussion with a blood pressure as low as 30 mm. Hg, the vasomotor centre may not be essentially paralyzed; indeed, that its reflex excitability is increased; so that electrical stimulation of the sciatic or brachial may meet with an even greater percentage response than under normal conditions.

If the condition of concussion were identical with that of shock, we should expect those means to be of value which Leonard Hill, Crile, Howell, and others during the last few years, have proved to be of use in shock, chiefly those that constrict vessels and restore peripheral vascular tone, such as bandaging the limbs, compression of the abdomen, Crile's pneumatic suit, intravenous injections of salt solution and adrenalin, or alkaline solutions of sodium carbonate (Howell), and with this the head-low position, and warmth to the body. I have already indicated certain differences between these two conditions which, theoretically, lead us to think that they are not identical. Nevertheless, in their clinical aspects, as evidenced by the effect upon the vital centres, they are so alike that one might reasonably employ these various measures in cases in which early death seems imminent. I have found in the literature no experimental work bearing upon this treatment of shock in cases of severe concussion. Hitherto the purely expectant treatment of concussion, including the traditional ice-cap to the head, has held sway, and doubtless, in most cases, with perfect right. *Nil nocere!* The thoughtful surgeon, nevertheless, must ask himself whether some patients in this dangerous state, with a blood pressure well below 100 mm. Hg and steadily falling, as judged by frequently repeated observations, together with all the classical symptoms of severe concussion, might not be saved by active interference along the lines suggested.

In this connection the reader will recall the striking experiments of Leonard Hill, which showed the extreme importance of gravity in the causation and treatment of shock; and how support of the splanchnic territory, either by the feet-up position or by compression of the abdomen, or both, was effectual in raising a perilously low blood-pressure and restoring the animal. Kocher strongly advises the head-low position.

The value of strychnine in shock is still a moot question. Crile considers it actually harmful in conditions due, not to hemorrhage, but to exhaustion from over-great sensory stimulation; it is then, he says, a mere whip to the tired horse. On the other hand, Cook and Briggs give it a high value, and use it in heroic doses, up to gr. $\frac{1}{15}$ at a time; and they produce blood-pressure charts in cases of deep shock to support their belief. Alcohol, digitalis, ergot, and other stimulants are of very doubtful benefit. On the other hand, absolute rest is of great importance. Quietness, a dark room, and as little handling as possible are necessary; in other words, the cutting off of all unnecessary afferent impulses.

3d. In the third class, the patients who recover, treatment must consider three possibilities: the stage of reaction; the development of complications, such as focal or general signs of compression, and inflammation; and the late results.

As to the first, no special measures are needed. The febrile reaction must represent that which is natural to injury with blood exudation anywhere, but modified by the conditions of intracranial circulation and pressure. So long as it is merely febrile, it may be left to itself. One symptom, however, demands relief: with the return to consciousness, headache nearly always appears, and it may be agonizing. Presumably it is due to tension on the dura, the result of effusion of blood or serum. It often disappears in a few days, but may last for a very long time. Ice to the head may give relief. Otherwise, morphia is advisable. If cerebral compression of any severity is absent, the withdrawal of 10 to 15 c.c. of fluid by lumbar puncture is without danger, and may often give relief. The administration of sedatives and cathartics may also prove beneficial.

The development of complications must be watched for with the greatest care. It has been pointed out that although transitoriness of the symptoms is an essential characteristic of concussion, there still occur in most instances widespread focal lesions of small size in the brain substance, not of sufficient size nor so situated as to cause well-defined localizing symptoms. From this it is but a step to the larger contusion or hemorrhage which needs only the accident of situation to furnish localizing signs, and that of size to call forth the symptoms of pressure on the medulla, the so-called *general* signs of compression. The duty of keeping a close watch for such signs is very great. If they are found, it signifies the probable effusion of blood or serum, and therefore the presence of compression. And whereas no operation can be done in pure concussion, an operation for consequent compression may be very urgent.

It has not been the custom in the past to trephine, unless in the presence of well-marked focal signs, chiefly of the motor area. I believe that even in the absence of all focal signs, if one finds evidence of general compression supervening to a dangerous extent in concussion, one should do decompression, and best by Cushing's intermusculo-temporal operation. Often one will be able to evacuate blood at the base, and by the removal of bone give space for the œdematous brain.

In the absence of all indications for interference, it is still advisable that the patient should rest in bed for several weeks at least, and later avoid everything that tends to raise blood pressure—constipation, work, over-eating and over-drinking, above all, alcohol. It is the patients who insist on resuming work early that show most the late development of motor and psychic asthenia.

VI. CONTUSION OF THE BRAIN.

This term in its ordinary acceptation indicates a bruising, with or without actual laceration, of the brain substance from whatever cause. In the first place the violence may be direct, as in the case of depressed fractures or punctured wounds of any kind. Here there is actual bruising, often combined with cutting or tearing of the tissue. The larger group, however, of contusions is the result of indirect injury, the injury, in short, which ordinarily causes concussion; and the mechanism of contusion in these cases is the same as that which has been described under Concussion.

The cause of the minor lesions of concussion is the change of shape in the brain following that of the skull, its propulsion against one side of the cranial box, and the sudden displacement of cerebro-spinal fluid. The force which causes these small lacerations may, if increased, cause large lacerations by the same mechanism, and, if the laceration happens to involve a vessel of any size, there will occur a hemorrhage of variable extent at that spot. Frequently the vessel escapes, and we then see merely a laceration.

All these various anatomical lesions are the result of concussion in the clinical sense; and they may be quite independent of any material hemorrhage, sufficient, at any rate, to obscure by compression the signs of concussion. Contusion is only a severer injury, anatomically considered, and means a greater degree of violence. Clinically speaking, whether an injury produce minute tears—concussion so called—or large tears—which is concussion plus contusion

—makes but little difference in the symptoms, save as these are the expression of the localization of the tear, and represent a disturbance of known function. These last are discussed in a separate section upon the Localization of Function in the brain, while those of concussion have already been described.

VII. INJURIES AND DISEASES OF THE MENINGES.

Anatomical Considerations.—THE DURA MATER.—The attachment of this membrane to the skull varies in different regions; generally over the vertex and the vault it can be separated from the bone with reasonable ease. At the base, however, it is closely adherent to the bone, and, as one observes in post-mortem examinations, can be pulled off only with the exercise of some force. In the middle fossa, however, on its lateral aspect, and in the cerebellar fossa, this closeness of attachment is not so great, and operations in these two regions are not accompanied by material difficulty from this cause. Its close attachment at the base carries with it, in many instances, a tear of the membrane (periosteum) when the bone is broken, yet the same condition prevents the extravasation of blood between itself and the bone in bleeding from the fracture. Thus it is that lumbar puncture in cases of fracture at the base nearly always shows the presence of blood in the subarachnoid space; while at the post-mortem examination any extradural bleeding there may be is rarely found at the base.

Being lined on its inner surface with a layer of endothelial cells, the dura forms a smooth covering for the subjacent meninges and cortex. When it is wounded to any extent, adhesions are apt to form between it and the latter, just as occurs with any other endothelial-lined cavity. Yet, if the dura is carefully sutured, such adhesions will frequently not form—a point that is important to remember in the matter of intracranial operations.

The dura represents the true periosteum of the cranium in the sense of possessing a very large bone-forming faculty, in contradistinction to the pericranium or external periosteum. In consequence of this fact, trephine openings are usually, if not too large, filled up with true bone in the course of time.

The membrane in places is composed of two layers. Between these run the venous sinuses. These are, from the surgical aspect, of very great importance in many respects, above all in the fact that under severe compression they may, like the ordinary veins, become obstructed by the extravascular pressure of the brain and in this way oppose great hindrance to venous outflow. The general course and relations of the longitudinal and lateral sinuses have been already touched upon, and are sufficiently illustrated in the accompanying plates (XXXI and XXXIV), and the cavernous sinus is referred to in the section on Thrombosis of the Sinuses. The others have a much less degree of surgical interest. The superior and inferior petrosal are rather closely attached to the petrous bone, and are especially exposed to tears in fractures of the middle fossa; the occipital sinus, which connects the torcular with the venous plexus of the spinal canal, has to be regarded in operations upon the cerebellar region, but is small and may be easily tied. Vessels of the diploë are much larger and possess a much more systematized arrangement than is commonly thought. (See Plate XXXI.) They occupy a very important place as being side channels for the intracranial venous blood when the normal exits of the latter are blocked.

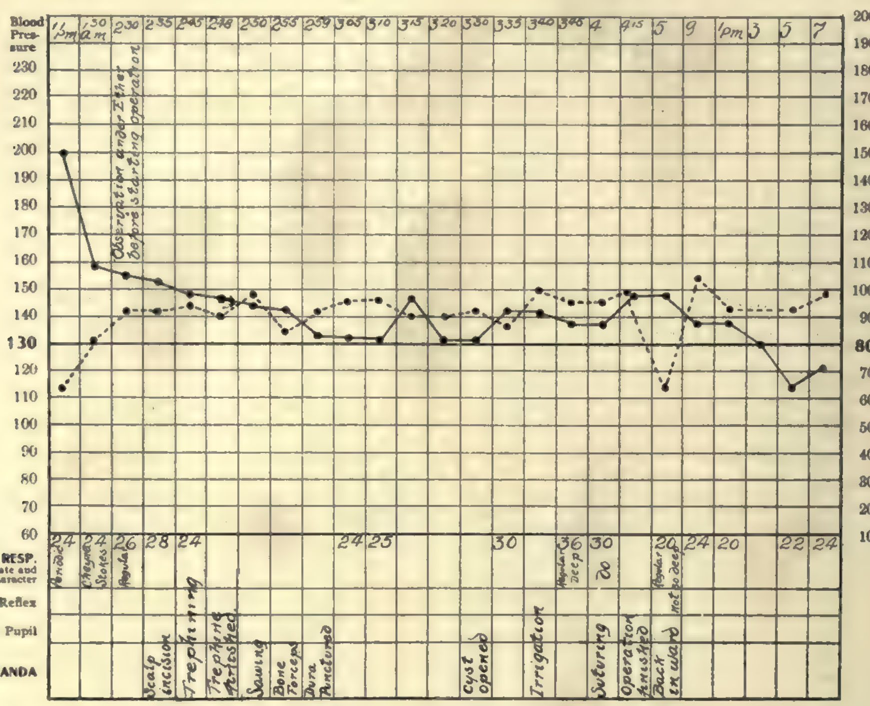


FIG. 36.—Record of Blood Pressure (solid line), Pulse (dotted line), and Respiration During Evacuation of a Large Traumatic Intradural Cyst and for Fifteen Hours After Operation. Note the coincident fall of blood pressure and rise of pulse rate, evidencing the relief of compression afforded to the vasomotor and vagus centres; also the change of breathing from "periodic" and "Cheyne-Stokes" to "regular." This last was accomplished by the mere giving of ether without rise of blood pressure—probably a direct effect on the heart. The pupillary phenomena are not here inserted because of previous use of a mydriatic for examination of the backgrounds of the eyes. For the clinical history of this case see page 195.

Under such circumstances, especially in general compression, they convey to the external coverings through their emissary veins a part of the venous blood from the cerebrum; and hæmostasis during operation may be rather difficult. It is important to remember the situation of the chief emissary veins (see Plate XXXI, Fig. 1), inasmuch as, during operation, the bleeding from one of these may be alarming. They are situated, one in the posterior mastoid region; one or two in the occipital region at the level of the occipital protuberance, alongside the occipital sinus; a frontal one close to the supra-orbital notch; and one at the parietal foramen, near the midline of the vertex. These frequently unite the sinuses directly with the veins of the scalp. The mastoid emissary is perhaps the largest, and must be avoided, if possible, when removing bone in cerebellar operations. A wound of it is practically a wound of the lateral sinus. The condition of this vein often indicates what is the condition of the lateral sinus—*i.e.*, whether it is thrombosed or not.

It is important to know to what extent it is permissible to ligate the various sinuses without too much risk of cutting off the return flow. The longitudinal sinus may usually be tied in any part of its course. One lateral sinus may be tied; but the ligature of both may cause death from venous stasis. The cavernous sinus may be blocked. In fact, it frequently is filled up by thrombus. The result will be some exophthalmos for a while, but life is not usually endangered. Of all the sinuses, the sinus rectus is probably that which is most indispensable. It drains the veins of Galen, and these receive the blood from the choroid plexuses and the central portions of the brain. A closure of the sinus rectus, such as occurs sometimes in thrombosis or by pressure of tumors, will usually be followed by acute hydrocephalus, or the ventricular fluid may even become seriously blood-tinged.

It remains to mention the close union of the sinuses with the skull wall, to which they are bound by fibrous tissue, by the emissary veins, and by the rigidity of their inelastic walls. Their course, also, especially that of the lateral sinus, lies in a depression of the bone, a regular furrow. These circumstances not only render them more liable to be torn by the distortion of cranial shape that precedes fracture, and by the bony edge of the fracture line itself or of splinters, but also prevent the spontaneous cessation of the bleeding. The opening in a sinus remains gaping. That wounds of sinuses are nevertheless comparatively infrequent is probably due to the thickness and strength of their fibrous walls. The longitudinal sinus, enclosed as it is in the somewhat movable falx, has a better chance of escape, and lies much less in the path of fractures than the lateral.

Between the dura mater and the arachnoid lies a potential space, commonly called the *subdural space*, which is quite free, save where the arachnoideal villi or Pacchionian granulations become attached to the dura. When blood breaks through the arachnoid, it can spread freely in all directions in this subdural space, as long as it remains fluid, even causing marked distention.

For a description of the structure of the *arachnoid* and *pia mater* we must refer the reader to text-books on anatomy. From the surgical side, it is important to remember chiefly the spider-web character of the tissue, which disposes it on the one hand to the retention of effused fluid in its meshes, either as a generalized cortical œdema or as cortical cysts, and on the other hand to the rapid diffusion of infection through the contained cerebro-spinal fluid.

Effusions of Blood within the Cranium.—The classification of intracranial bleeding is more rationally based upon the anatomical situation of the blood effused than upon etiological considerations. From this standpoint we may divide the subject into three main classes, according as the blood is extradural, intradural, or cerebral in origin. The second of these may be further divided into two subclasses according as the blood is found between dura and arachnoid, or between arachnoid and cortex in the pia. In all these cases traumatism is by far the most frequent cause.

Factors in the Causation of Intracranial Hemorrhage.—While these three classes, by virtue of their differing anatomical positions, may vary widely in their etiology, course, prognosis, and treatment, and exact therefore separate consideration, there still exist certain causative factors which are common to all, and which may well be discussed in a preliminary paragraph.

If we have gained a proper comprehension of the mechanism of fracture and of the causation of concussion and contusion, we shall have no difficulty in understanding the pathology of traumatic intracranial hemorrhage. The deformation, local and general, which has been shown to follow any severe violence to the skull, whether it go on to fracture or not, or whether the fracture be depressed or fissured, may, naturally enough, result in tearing of the vessels that lie closely connected with its inner surface—that is, the middle meningeal arteries and the venous sinuses. Not a few instances are on record in which a tear of the meningeal artery, even of both arteries, has occurred without fracture in the bone; a striking proof of the skull's elasticity. However, if the cranial deformation does go on to fracture, the edge of a fissure or the point of a splinter may perforate these vessels, as well as the pial or the cerebral vessels. The various agents which cause punctured fracture of the skull, including firearms, may do the same.

On the other hand, the pial and cortical vessels may be torn by the impact of brain against bone as opposed to that of bone against brain. The impact of a rapidly moving body against the skull drives the brain bodily against the opposite side of the cranium; and this contre-coup violence tears the pial and cortical vessels, besides bruising the cerebral substance. Witness the frequent hemorrhages and contusions over the inferior surface of the temporo-sphenoidal and frontal lobes in the neighborhood of the sella turcica and the sphenoidal wings, to which Duret thirty years ago, and more lately Walton, have called attention. A case of concussion must be mild indeed in which some slight bleeding from pial vessels does not occur; and, on the other hand, it is amazing how trivial this violence apparently is in instances of serious intracranial hemorrhage.

The same mechanical principles are sufficient to explain the occurrence of traumatic hemorrhages in the cerebral substance. As before, the impact of a blow drives the brain onward in the cranium by imparting to it its own movement; but it also changes suddenly the shape of the brain in the same sense as that of the cranium. The necessary result is compression of nerve substance in one diameter, and distraction in the other two diameters at right angles to the first; and therewith a tearing, not only of nerve fibres, but also of vessels. It is natural, moreover, to assume that the sudden arrest of this driving movement against the cranial surface must add a further effect of distortion or tearing apart to that already indicated, by reason of the *tassement*, or piling up, of the posterior portion upon the arrested anterior part. Whether the resulting hemorrhage be minute or large must depend on the size of the vessel torn; and this is so subject to accidental factors that it can never be predicated in any given instance, whether from the degree, the nature, or the direction of the violence. Apparently slight concussion may be complicated by a large intracerebral clot without other visible hemorrhages; while severe traumata may show multiple points of bleeding, of which no one is larger than a pin's head.

Extradural Hemorrhage.

Pathology of Extradural Hemorrhage.—Blood effused outside the dura usually comes from a ruptured branch of the middle meningeal artery, occasionally from one of the sinuses, rarely from a diploëtic or emissary vein, and very rarely from pial vessels inside the dura through a rent in the latter. In a series of 50 autopsies upon cases of cranial fracture, the writer found hemorrhage outside the dura in 24. It is interesting to note that of 18 of these, in which the situation of the blood is noted, 13 were found in the lower temporo-parietal region, that is, in the area of the trunk and large branches of the middle meningeal artery; in 2, the clot was at the base; in 2, in the occipital region; in 1, in the cerebellar fossa. In 3 instances there was effusion on both sides. Although in these cases the exact source of the bleeding was frequently not mentioned, the figures indicate the great relative frequency of rupture of the middle meningeal artery.

Middle Meningeal Extravasation.—It has been generally believed, on Prescott Hewitt's authority, that the extradural form represented eighty-five per cent of all cases of intracranial bleeding. Frequent opportunity to examine cases on the operating table or in the post-mortem room has led me to consider this belief erroneous. Intradural is much more frequent in all respects than extradural hemorrhage. The blood effused as the result of a rupture of the middle meningeal artery or one of its branches occupies a fairly constant position inside the cranium. The surgical anatomy of this artery is well known. Its course is sufficiently demonstrated in the accompanying figure illustrating Steiner's research. (Fig. 37.) A middle meningeal clot occupies, in the great majority of cases, the lower and anterior parieto-temporal region. And this constancy of situation is due to several circumstances: the frequency with which injury and the resulting fracture involve the lateral aspects of the skull and the middle fossa of the base; the greater ease with which the dura is peeled off the cranium in this region than elsewhere; and, finally, the fact that the greater number of the branches of the middle meningeal as well as its trunk lie here. The terminal branches are seldom wounded, perhaps because it is rare for a fissured fracture to extend high up on the side of the cranium; but if wounded, being small, they seldom give rise to a severe hemorrhage. The same is true of extradural bleeding from a sinus; in either case blood pressure is too low to separate the dura from the bone over any wide area. A notable exception is the case of Kroenlein,* where an effusion covering the greater part of one side of the dura came from a tear of the lateral sinus.

FIG. 37.—Topographic Anatomy of the Middle Meningeal Artery, and Steiner's Method of Trephining for Hemorrhage from this Vessel. *a*, Anterior branch; a^1, a^2, a^3, its three branches; *f*, frontobasilar branches; *o*, orbital branch anastomosing with the ophthalmic artery; *p*, posterior branch; the dotted line p^1 represents an anomaly, in that the posterior branch takes a deep origin in the foramen spinosum and runs more nearly vertically; the dotted line below a^3 figures an abnormal course of the normal branch a^3. I., Vogt's localization of the trephine opening for middle meningeal clot; II., Kroenlein's anterior and posterior openings; and III., Witherle's opening for the same. The two circles not otherwise indicated represent the anterior and posterior openings advised by Steiner. (See text for particulars.)

The posterior branch of the artery is much more rarely ruptured than the anterior; and in these instances the clot lies usually under the postero-inferior portion of the parietal bone, about on a level with the supraorbital ridge and vertically above the posterior part of the mastoid process. Still more rarely is the hemorrhage anterior to the temporal region, in which case it comes from an abnormal course of the anterior branch. If the bleeding arise from one of the sinuses, or from an emissary vein, the clot will, of course, vary in situation. Thus it may be frontal, occipital, or cerebellar. Cushing reports the case of a large bilateral frontal extravasation, amounting to 230 c.c., which had been effused from emissary veins. Sometimes in craniotomies the separation of the dura from the bone will rupture an emissary vein and cause hemorrhage which is quite difficult to arrest.

* Kroenlein: Deut. Zeit. f. Chir., 1896, Bd. xxiii., p. 209 *et seq.*

The blood is not infrequently effused within the dura mater when the latter is torn by a coincident fracture. If there be present an open wound, the blood may easily be poured out externally. Coincident lesions of the sinuses are rare; but such lesions of the pial and cortical vessels are quite frequent.

As stated above, the site of the tear in the artery varies. It is usually low, and involves one of the anterior branches, rather rarely the posterior branch; occasionally the trunk itself near or even in the foramen spinosum is torn.

The size of the middle meningeal clot is ordinarily large. From four to six ounces have been recorded not infrequently. In one instance on record a hemorrhage of six ounces on each side was found; this is unique. In such extreme instances the effusion must have occurred very slowly, allowing the brain to adapt itself; otherwise death would inevitably have resulted from transmitted bulbar compression long before such amounts were reached.

The idea that the clot, once the bleeding is arrested, might, if left alone, undergo reabsorption or organization, is quite illusory; experience shows that even in those instances in which the cerebral compression remains stationary at what is apparently a safe level, yet the persistence of this compression ultimately exhausts the conservative resistance of the vasomotor centre, and after a few days there suddenly occurs a fall of blood pressure and death supervenes rapidly.

In shape the effusion is ordinarily round and convex, like a watch-glass. Naturally it compresses the underlying brain to a degree corresponding with its own thickness. A classical illustration, much reproduced, yet still worthy of reproduction, is that of Anger. (Plate XXXIII, Figs. 1–2.) Other instructive ones have been put forth by Harvey Cushing and Connell.

Intradural Hemorrhage.*

Pathology.—From anatomical considerations it follows that blood situated in the space between dura and cortex may originate in the rupture of a dural, a pial, or a cortical vessel. In the first instance the blood may come from one of a number of sources, such as the middle meningeal artery or one of its branches, or the internal carotid; one of the venous sinuses, and, as a matter of fact, either the lateral or the longitudinal; finally, a vessel in a dural false membrane, the so-called hemorrhagic pachymeningitis. In the two first instances the dura is torn. In these cases the blood will be outside the arachnoid. Where a pial vessel is ruptured, it will occupy primarily the meshes of the pia-arach-

* In speaking of intracranial hemorrhage, the writer prefers to use the term intradural, as opposed to subdural, to designate effusions between dura and cortex. The word "subdural" is employed only to designate the space immediately underlying the dura, as being in this connection more precise in its meaning than "intradural." The term "epidural" is abandoned.

noid, either deep between pia and cortex, or more superficially between pia and arachnoid—subpial or subarachnoid. Where the vessel torn is cortical, the blood will be primarily subpial. It is evident that, whether by the violence of the trauma or of blood pressure, the effused blood may break through the meshes of the pia-arachnoid inward or outward (usually the latter) and either disrupt the cortical substance or spread freely in the subdural space. It is also evident that the blood may spread laterally through the meshes of the subarachnoid tissues in the subarachnoid space, or may dissect the pia from off the cortex. Indeed, this lateral spread is often very extensive, so that a whole hemisphere (6 times in 50 autopsies on fracture cases) or the greater part of both hemispheres (11 times in 50 autopsies) may be found covered with a thin sheet of clotted blood contained in the meshes of the arachnoid and in the subarachnoid spaces. The size of the hemorrhage varies from the punctate extravasation through all degrees up to a large mass, chiefly at the base. The situation of the hemorrhage corresponds, for the most part, to the area injured. The frequency, however, of contrecoup bleeding is surprising. One is naturally unable to estimate the frequency of its occurrence in cases of recovery; but where the injury has been so severe as to cause death the hemorrhage will always be found in the pia over the area of brain opposite the site of violence. In the series of 50 autopsies already mentioned, intradural meningeal hemorrhage was found 31 times; extradural, 24 times; and both coincidently, 14 times. In the writer's opinion, some small amount of hemorrhage from the pial or cortical vessels is an almost constant event with traumatisms of any severity, including those from which recovery ordinarily takes place without symptoms other than those of concussion. The evidence for such a view is found in many of the cases that come to an autopsy from causes other than that of the cranial trauma, such as pneumonia or injuries in other parts of the body. Here autopsy frequently reveals sheet hemorrhage in the pia-arachnoid covering even large areas of the cortex, yet plainly incapable of having been the cause of death. This the writer has confirmed also, as far as possible, by observations at an abattoir. The usual method of stunning an animal is to strike it in the middle of the forehead, just anterior to the horns, with a sort of pole-axe provided with a short spike to insure fracture of the skull. In the brains subsequently removed, within a half-hour at the most, I constantly found more or less diffuse subarachnoid and subdural hemorrhage at the site of injury, and also at the base, over the contrecoup area, a similar effusion, which was, however, usually limited to the subarachnoid space. When, in order to reduce the degree of direct violence associated with the fracture, the blow, at my request, was delivered with the blunt side of the instrument and upon the back of the head just behind the horns, the immediate loss of consciousness and the general flaccidity characteristic of concussion were equally well obtained, but the brain on removal showed a much slighter degree of meningeal hemorrhage. Yet, and this is the point, such hemorrhage was constantly present. It was found more regularly at the base in the area of contrecoup than in the part subjacent to the injury; and it was situated always in the pia-arachnoid. I think there can be small doubt but that a certain moderate degree of hemorrhage into these membranes accompanies a majority of all but the milder cases of concussion. In this sense intradural hemorrhages which, in the general mind, are much less frequent than the extradural, in reality are much more frequent, but, giving rise to no symptoms, or to none that call for operation, pass unnoticed under the rubric of concussion.

When the blood from a torn pial vessel breaks through the arachnoid, one would expect it to spread without hindrance to the dependent parts of the cavity; and this it not seldom does. Yet in many cases it remains circumscribed; and such circumscribed collections have an identity of their own of no small importance, inasmuch as they frequently simulate very closely the extradural hemorrhage. Their mode of origin is not quite clear. Probably a primary small hemorrhage clots at its periphery; whereupon, later, the rise of blood pressure coincident with the passing off of the concussion effects, occasions, when the patient stands up, walks or vomits, a secondary hemorrhage into this circumscribed area; and, if this last be not too violent, the whole remains localized.

Fate of the Effused Blood.—There can be no doubt but that the thin sheet clot of small pial hemorrhages, probably present in most instances of concussion, is ordinarily reabsorbed without causing symptoms and without leaving trace. At the most, veil-like adhesions may remain, thickening the structure of the pia-arachnoid to a varying degree, yet often, doubtless, so little as to pass unnoticed save under close observation at a possible subsequent autopsy. The conditions for reabsorption in the intradural space are largely more favorable than in the extradural, owing, probably, to the diluent action of the cerebro-spinal fluid, and its free exit into the veins.

Likewise, blood effused outside the arachnoid usually disappears more or less completely. If the clot be large, however, there will frequently remain thin adhesions between arachnoid and dura. For a long time one may find in these adhesions, and more particularly on and in the cortex, the traces of the earlier hemorrhages in the shape of pigment spots, and in the brain substance a diffuse yellowish stain.

Arachnoid Cysts.—At times, for some reason that is still unclear, the breaking down of the clot does not go on to reabsorption, but rather to the formation of a cyst, which may be situated either in the pia-arachnoid or, perhaps more frequently, between dura and arachnoid. Such cysts usually acquire gradually a fibrous wall of their own, through organization of the outermost layer of blood-clot from vessels either in the dura, close against which they lie, or in the arachnoid. Prescott Hewitt was one of the first to call attention to them; but those he described represented a very late condition with organization complete. He had noticed, however, such cystic collections well defined as early as the twenty-third day; and subsequent observation has not only confirmed this, but has traced their formation from the first few days following the trauma. Bowen, in an analysis of 72 cases of intradural hemorrhage taken chiefly from American and English literature up to 1905 (Guy's Hosp. Rep., Vol. LIX.), found 12 instances of this condition; and the writer has lately operated upon a patient in whom, two months after the injury, this lesion was found. As in this instance, so in many others, the contents of the localized collection are found to correspond fairly well with what one has learned to expect in hemorrhagic cavities elsewhere. Within the first week the effusion is still largely composed of dark blood, partly fluid, partly clotted, with an unimportant admixture of serum or cerebro-spinal fluid. In the second week and later, the proportion of the latter becomes greater, fluid blood as such disappears, the clot becomes gradually disorganized and broken up into small shreds. Definite clot, however, may still be found as late as the seventieth day; and in the writer's case there was still present, at the end of sixty days, a small amount of blackish clot overlying the pia, and floating in shreds through the cyst contents, which consisted of approximately 7 or 8 oz. of light-brownish serous fluid. The outer wall of this collection was a dark-red membrane, a few millimetres thick, closely applied and lightly adherent to the dura. It showed in microscopical section nothing but a layer of early granulation tissue thickly studded with blood pigment, clearly the beginning organization of a layer of blood-clot. There was no clear trace of arachnoid tissue in this; and the pia with its vessels was seen covering the cortex at the bottom of the cyst at a depth of about two inches from the trephine wound. Such a condition, if long supported by the patient, would certainly have resulted in the typical organized arachnoid cyst of Hewitt. On analyzing the comparatively meagre literature of intradural hemorrhages, one finds a dozen or more analogous instances. Bowen (*loc. cit.*) discusses them; and they are found without particular mention in Brion's series of 50 cases (Doktor Thesis, Strasburg, 1896) and in the 21 of Scudder and Lund (*American Journal of the Medical Sciences*, April, 1895). Starr's series ("Brain Surgery," 1894) also consists largely of such partly localized collections.*

Localized Traumatic Serous Arachnitis.—While the localized intradural effusion is within the first few days practically always blood or blood-clot, it may in rare instances consist chiefly of a clear or blood-tinged fluid, the nature of which, whether exuded blood-serum, lymph, or cerebro-spinal fluid, has not yet been determined. In any case, it is certainly the product of acute reaction to injury. A striking example of this occurred in the service of Dr. Garrow. (R. V. H. Surg. Reports.) Trephining, undertaken within twelve hours of the accident, under a probable diagnosis of middle meningeal hemorrhage, revealed

* See also Ballance: Lancet, Dec. 21st, 1907.

nothing more than a localized collection of faintly blood-tinged serum under the dura, which had so depressed the brain that one might place a goose-egg in the hollow. I have observed one other case, probably of this nature, in which localized symptoms of pressure receded within two days without operation. Walton has called attention to the condition (*American Journal of the Medical Sciences*, Vol. CXVI., p. 267), and has reported four cases, only two of which were confirmed by operation. Why the fluid should persist as a source of localized compression, why it does not spread through the arachnoid and become absorbed, is not clear. In the literature there is apparently only one other similar condition recorded at so early a date, though a few examples belonging to the later days of the first week are to be found. Hartwell's (*Annals of Surgery*, June, 1906, p. 934) patient was a boy who had fallen on his head. He was admitted to hospital, and two and one-half hours later Hartwell operated on him because of rapidly increasing coma and cerebral excitability. There were no localizing symptoms. Upon trephining under the temporal muscle, according to Cushing's method, bloody cerebro-spinal fluid spurted out under tension; and the boy shortly recovered.

The clot may suppurate by infection through a compound fracture. This is an ordinary matter. But it may also suppurate when bone and scalp are intact, the infection coming undoubtedly by way of the blood, as has been observed by Elder, whose case of typhoid infection of an extradural clot is probably unique. (*Annals of Surgery*, January, 1908.)

General Symptoms of Intracranial Hemorrhage.—The symptoms of acute progressive hemorrhage within the intact cranium, whether extradural or intradural, are chiefly those of cerebral compression in so far as they are not masked by the coincident condition of shock or concussion.

In a general way, the two cardinal signs of hemorrhage are, first, the free, or latent, or lucid interval; and, second, the progressive aggravation of symptoms.

The *free interval* has been regarded for many years as the one classical sign of extradural, and more particularly of middle meningeal, hemorrhage. J. L. Petit, in the eighteenth century, recognized its value as a sign of bleeding, and interpreted it correctly. Jacobson, whose analysis of 70 cases (Guy's Hosp. Reports, 1886) was the first serious study of this lesion, believed, though mistakenly, that it was an almost constant symptom. Its interpretation is clear. A man in falling strikes his head, and is immediately unconscious. As this effect of concussion passes off, consciousness returns. Or, there may have been no loss of the senses. In either case, after an interval of clear mind, which may last a few minutes, or hours, or days, or even, it is said, several weeks, unconsciousness returns. This is the so-called free, or lucid interval. It represents the time required by the blood effused to induce such a degree of general compression as to cause unconsciousness. At first, doubtless, blood pressure is low as an effect of the concussion, and the blood is driven out of the artery with no great force. Yet with recovery, and especially with the rise in blood pressure consequent upon standing up, walking, or working, the effusion increases more or less rapidly. The pressure which it exercises is nevertheless compensated for some time (as has been explained in the section on Compression), in spite of the establishment of a vicious circle, by a rise in the general blood pressure and by a driving out of the fluid contents of the cranium. Even after this compensation stage, there will often appear a stage of manifest symptoms—headache, increased excitability of the reflexes, dizziness, vomiting, psychical irritation in the way of delusions or delirium—before the unconsciousness proper which terminates the free interval. All this indicates clearly an advancing cerebral compression, which in the vast majority of instances is due to the progressive extravasation of blood. In rare instances it may be, not blood, but a localized collection of serous or cerebro-spinal fluid, an example of which I have already related. It must be remembered that the free interval may be exceedingly short, so much so as to escape the notice of bystanders. On the other hand, it is possible for consciousness to be largely retained for a long time, even till near death, the patient showing evidence only of cortical irritation (excitement, delirium, restlessness, hallucination, and so on) and dying from bulbar, rather than cortical, failure.

The *progressive aggravation of symptoms* is really, in its essence of the same nature as the free interval, and due to an increase in the blood effused. In many cases where the patient comes under observation in an unconscious condition, it will be impossible to secure a history of any lucid interval; yet continuous close observation may reveal a definite march of symptoms either of local or of general compression. An exaggerated reflex may disappear, a spastic limb become flaccid, a monoplegia become a hemiplegia, a contracted pupil dilate; the pulse may grow slower; an even respiration may become deep, stertorous, or irregular; blood pressure may rise; stupor may turn to coma—all just so many clear indications of the continued pouring out of blood.

These indications are plainly very general ones and suffice for no more than the general diagnosis of hemorrhage. Whether the blood is situated inside or outside the dura, or in what part of the cranial cavity it lies, are questions that can be diagnosed only by closer observation.

Symptoms of Middle Meningeal Hemorrhage.—Coming now more particularly to the symptoms proper to middle meningeal hemorrhage, one finds that they are those of compression, local and general. A typical case-report may perhaps best illustrate the chief ones (Royal Victoria Hospital Surgical Reports, Book LXXVIII., p. 106, Dr. Garrow's service):

The patient was admitted at 9 P.M., September 25th, 1906, with the following history: At 8 A.M. of the same day he had been struck on the head with a heavy stick, and was unconscious for three hours. He had, by this time, recovered sufficiently to answer questions and to make complaint of pain. At 2:30 P.M. he lapsed again into unconsciousness, which had persisted till the time of admission. Upon examination he was found to be semiconscious; he would not respond to questions, yet would vaguely resent manipulations. There was a wound over the vault in the left parietal region. Pulse was 64, of good volume and tension; blood pressure 160 mm. Hg; respiration 30; the pupils equal, contracted, and feebly reacting; and there was some paresis of the right arm. Sensation also, as judged grossly by pin-pricks, seemed to be diminished over the right face and arm. The fluid withdrawn by lumbar puncture contained blood. Otherwise nothing of importance. On account of deepening unconsciousness and increase in the degree of paralysis, he was trephined, at 11 P.M., a little behind the usual situation, above and anterior to the left external auditory meatus; and about two ounces of extradural clot were removed, the bulk of which lay just posterior to the opening. No actual bleeding-point was found, but oozing was stopped by gauze packing. Blood pressure fell, within ten minutes of the evacuation of the clot, from 160 to 144 mm. Hg, while the pulse rose from 60 to 88, evidencing clearly the relief of cerebral compression. He gradually became clear and recovered completely in three weeks, although a period of restlessness and delirium intervened, probably the expression of further lesions under the dura.

Compression Symptoms.—With an effusion that occurs nearly always over or close to the motor region, and whose quantity, by virtue of its being forced out under high arterial pressure, is usually quite large, it is natural that the symptoms of local and of general cerebral compression should be both regular and marked. It is a lesion that reproduces with great exactness the experimental conditions of Duret, Pagenstecher, Horsley, von Bergmann, Cushing, and others, and is followed with almost the same certainty by the same symptoms. It is only when the disturbing element of severe concussion comes in that the picture is clouded. In the ordinary case in which the primary concussion, if present at all, passes off, one expects to find two classes of symptoms: those depending on pressure directly upon the underlying cerebral cortex, and those resulting from the transmitted pressure with consequent bulbar anæmia.

Local Symptoms.—Those of the first class comprise the usual Rolandic symptoms. Face and arm are frequently paralyzed; but the leg area, situated as it is, high up in the tract, while the effusion ordinarily extends only from below, often escapes. Certainly, the leg is never primarily affected. Where it is the first to be paralyzed, one may conclude with great probability against the presence of extradural, and in favor of that of intradural effusion. On the other hand, if the face be first and chiefly paralyzed, it is clear that the clot lies low down and anteriorly.

Mention should be made of the rare occurrence of the hemiplegia on the same side as the effusion. When the paralysis is on the same side as the injury, one naturally must first assume that the clot lies on the opposite side and represents a contrecoup effect, a matter of such frequent occurrence that it should be the rule to trephine in such cases on the side opposite the paralysis, not on the side of the evident scalp wound. Yet there are now on record a fair number of instances in which the paralysis was on the same side as the clot, a collateral or homolateral hemiplegia. Much has been written about this. (See Enderlen, *Archiv f. klin. Chir.*, 1907.) Ledderhose (*Arch. f. klin. Chir.*, Bd. LI.) in 1895 collected 48 cases in the literature, and Ortner 38 in 1897. (*Deut. med. Woch.*, 1897, No. XXIV.) Many of these cannot stand strict neurological criticism. The natural explanation lies in the assumption of an absence of decussation of the pyramidal tract; this, however, is a very rare anatomical anomaly. Oppenheim's criticism was that many of such instances depend on an overlooked contralateral lesion. Ortner is probably more nearly correct in saying that many are due to a mistake in diagnosis, in that what is taken for a flaccid paralysis of the side corresponding to the clot is in reality no more than the flaccidity of coma, and no true paralysis; while apparent strength in the contralateral limbs represents merely a contralateral exciting rather than paralyzing effect of the clot, inasmuch as such pressure may quite well cause movements which simulate perfectly the ordinary movements of volition. These are important points to hold in mind in the diagnosis of the side of the lesion, and also in the proper conduct to pursue during operation when one has failed to find the compressing agent at the first trepanation.

In rare instances there may be entire absence of unilateral paralysis, even when the depth of coma is insufficient to cause general flaccidity. The clot is then probably very low in the temporal region or quite posterior to the motor area.

In some cases, again, the pressure on the cortex is insufficient to paralyze, and one may find nothing but twitchings or convulsive movements of face or arm. These, however, possess a high diagnostic value, if definite.

In the case of left-sided hemorrhage, Broca's convolution, together with the anterior parts of the upper temporo-sphenoidal convolutions, will be compressed; and, when the patient still retains consciousness, a motor or sensory aphasia can occasionally be made out and is of great localizing value. This will often, however, be masked by an unconsciousness which is the result either of the primary concussion or of the advancing general compression.

Kroenlein divides the cases, on the anatomical basis, into anterior, middle, and posterior, according to the situation of the clot. What has been said concerns chiefly the first two; whereas, in the posterior cases such motor symptoms will very rarely be present. Yet in these rarer instances of rupture of the posterior branch (a few of which Kroenlein has reported) it may happen that localizing symptoms can be discovered. These will concern chiefly contralateral disturbances of sensation, anæsthesia usually, yet sometimes hyperæsthesia. In the usual befogged condition of the patient, these things, the demonstration of which requires especially clear answers, must often remain mere matters of conjecture.

Eye Symptoms.—(a) Ocular Muscles.—Paralysis of the third or the sixth nerve, leading to squint, ptosis, and dilatation of the corresponding pupil, is occasionally observed, and points to a basal situation of the clot. The action of the third in particular upon the sphincter of the iris has been largely investigated, although a paralysis of the third is by no means the only cause of dilatation of the corresponding pupil. In a general way it may be said that contraction or dilatation of the pupils is very inconstant, so much so that it is useless to quote figures; indeed, in the course of any one case the size of the pupils may change frequently. Only one thing seems certain, that the Hutchinson pupil—a widely dilated and fixed pupil on the side of the compression and a normal or contracted pupil on the other side—usually indicates a situation of the clot upon the side of dilatation, and at the same time gives a dark prognosis. It is, however, not frequently seen. Wide fixed pupils on both sides are found chiefly in the terminal stages where the patient is suffering from very severe concussion or compression. An inequality of moderate degree, particularly in the earlier stages, is not an unfavorable sign; indeed, I have observed it in milder cases diagnosed as concussion.

(b) Optic Discs.—The general impression has been in the past that a swelling of the papilla was a rare thing in intradural hemorrhage. This has probably been the result of lack of observation. von Schultèn was the first to draw attention to the fact that in acute local compression there occurred a definite series of vascular changes in the papilla, consisting in a dilatation of the veins, a contraction of the arteries, and a partial filling up of the physiological cup. And he pointed out that even with persistence of the compression these disappeared within twenty-four hours. Cushing, however, has lately emphasized the fact that a finer and more routine observation shows the presence of these changes in the clinical cases of intracranial hemorrhage with considerable regularity. He says that in recent traumatic cases it has proved of the utmost assistance, not only as an indication of circulatory disturbance, but also in determining the side upon which the primary focal compression is being exercised where compression is a local one. He points out, however, that it is necessary to be able to appreciate slight grades of venous stasis unaccompanied by extravasation, and an early œdema the size of which cannot be measured in diopters. Ordinarily speaking, such changes disappear, as they did in the experiments of von Schultèn, within a day or two; this has been our experience at the Royal Victoria Hospital. Yet in some cases, for one reason or another, probably where compression from the hemorrhage is advancing or persisting, there does develop even a high-grade choked disc within a few days, which may last for weeks or months unless compression be relieved. Kocher reports such instances.

General Symptoms.—The symptoms of general compression, also, both cortical and bulbar,—the slowed, high-tension pulse, the stertorous and irregular respiration, and the unconsciousness,—have been sufficiently discussed in the section on Compression. One need say here only that they, too, appear with remarkable regularity in this situation of intracranial bleeding, as opposed to their frequent lack in intradural hemorrhage; and the reason lies probably in the fact that the cranial space is rapidly and seriously diminished by a large effusion under high pressure; a pressure which is not only arterial as opposed to venous, but is also an abnormally high arterial pressure.

The slow pulse of vagus irritation is, however, frequently not present, particularly, as I have found in an analysis of fifty fatal cases of cranial fracture, in the more severe injuries. It may have passed over into a vagus-paralysis pulse by the time the patient comes under observation. Or, as Kocher points out, the fever incidental to cerebral contusion may increase its rate up to normal or above. Or the medulla may have escaped pressure by a descent into the foramen magnum. I believe also that in cases of severe concussion the effect of the latter may prevent the development of the usual vagal and vasomotor pressure symptoms.

The vomiting which occurs soon after the injury is due to concussion; but if it return after a free interval, it is a fair sign of advancing compression. The same may be said of incontinence of urine and fæces.

Diagnosis.—Unmistakable though the typical phenomena of middle meningeal bleeding usually are in the classical cases, it is necessary to realize that in very many instances a sure diagnosis is practically impossible. Brun's analysis of 39 instances from the clinic of Kroenlein showed that of these only 19 were correctly diagnosed during life. The difficulty is due chiefly, of course, to the severity of coincident lesions in the way of intradural bleeding, cerebral laceration, and concussion.

In a subsidiary way, one must mention the frequent lack of any free interval, or of any anamnesis at all; as also the obscuring effect of alcohol, which is so frequently the cause of the injury and a complicating factor in its course.

Where, however, the usual symptoms are present, it is necessary to differentiate extradural bleeding from a number of other conditions, of which may be mentioned, first of all, localized intradural hemorrhage, then the hæmatoma of pachymeningitis hemorrhagica, apoplexy, Bollinger's late apoplexy, and thrombotic softening.

The majority of instances of intradural bleeding, as discovered at operation, have been, as a matter of fact, operated upon under the mistaken diagnosis of extradural hemorrhage. We must first exclude, in any comparison of the two, all those very severe cases of concussion and contusion in which these conditions quite obscure the symptoms of clot compression. But in those instances in which compression symptoms stand out sharply, is there a clear clinical distinction to be made? We must answer that, neither as to general nor as to local compression signs, can we draw a sharp line of distinction between middle meningeal and intradural hemorrhage. Both may involve particular areas of the cortex, the whole cortex, or the medullary centres in an identical fashion; as indeed one would expect from any localized compression that is sufficient to transmit pressure widely. It is only in the matter of time relationships that a diagnosis becomes possible. The two indications of value are, the duration of the free interval, and the length of time usually elapsing before urgent symptoms leading to operation or to death develop. In extradural bleeding, at least from the meningeal artery, the free interval rarely lasts more than twenty-four hours, and is usually much less than this; whereas with intradural hemorrhage it occupies ordinarily several days, a difference probably corresponding to the difference in blood pressure in artery and vein. On the other hand, the lapse of time before operation or death in the former is usually less than three days, while in the latter it is nearly always over three days. Both may produce identical symptoms of localization, but where the leg centres are primarily affected one may conclude that the blood lies underneath the dura. In those instances of intradural hemorrhage where the blood is free in the subdural space, and is collected largely at the base or over silent regions, the very absence of localizing symptoms points to an intradural rather than extradural origin. Schultz* has pointed out that the bleeding from intradural vessels is apt to be more widespread than in the case of the extradural form, and to affect separated areas of the cortex, because the blood can spread more widely and irregularly. The symptoms, correspondingly, may show a lesion of the cortex unlike what is usual with the extradural form. When lesion of the basal nerves, apart from the third, is found, it also speaks for intradural bleeding in a general way, on account of the rarity of extradural hemorrhage at the base.

The pachymeningitic hæmatoma can hardly ever be diagnosed. It may be suspected if the history of accident is lacking and the patient shows a strong history of alcohol, lues, or Barlow's disease, and also if the hemorrhage has come on apparently spontaneously, after a more or less severe localized headache. In addition, an intermittent advance of the symptoms of compression over several days is suggestive.†

With regard to apoplexy, it is only necessary to say that it may, in certain rare instances, coincide with and apparently result from an injury. Under such circumstances, a sure diagnosis is practically impossible.‡

Bollinger's late apoplexy may occasionally be confounded with the late development of intradural hemorrhagic cyst; yet it will differ from this in the comparative suddenness of its onset.§

As to thrombosis with subsequent softening, leading to œdema and rise in

* Schultz: Inaug. Diss., 1897, quoted by Kocher.

† J. C. Munro: Boston City Hospital Reports, 1902.

‡ Pearce Bailey: N. Y. Med. Record, Oct. 1st, 1906.

§ Bollinger: "Ueber traumatische Spätapoplexie." Internat. Beitr. zur wissenschaftl Medizin; "Festschrift Rudolf Virchow," Bd. ii., p. 468.

cerebral pressure sufficient to give all the classical signs of general and local compression, it is clear that diagnosis from middle meningeal hemorrhage may be very difficult, if not impossible. In a case described by Apelt,* the typical picture of experimental local and general compression was produced by a thrombosis of the right Sylvian artery, as found post mortem. In a similar case reported by Enderlen, trephining was actually done under the diagnosis of hemorrhage. The great value of lumbar puncture in all these circumstances will be discussed in the section on Intradural Hemorrhage.

Prognosis.—The prognosis of middle meningeal hemorrhage, with and without operation, is well illustrated by the oft-repeated figures of Weismann. Of 143 patients treated expectantly, 90 per cent died; of those treated by operation, 33 per cent died. Jacobson's figures, according to which only 18 per cent recovered, were taken from reports of cases before 1886, and can no longer be considered of value. It is true that the mortality must always be relatively high, even with operation, on account of the frequent association of intradural lesions. The pial bleeding and the cerebral laceration, and particularly the less well understood lesions of concussion, quite apart from their directly damaging effect in the way of shock and compression, have the result of obscuring very frequently the diagnosis of extradural clot, and in this way conceal the indications for an operation which might otherwise be life-saving. As to particular symptoms, it is probable that the degree and persistence of immediate unconsciousness is our surest guide. Cases which show no free interval give a dark outlook. Of 28 fatal cases of fracture of the skull, analyzed by the author, in which there was a note made upon this point, there were 18 in which there was no free interval, and of these 16 died before the lapse of twelve hours, the other 2 lived one and two days respectively. In the remaining 10 a free interval was present, and life was prolonged from one and one-half to thirty-two days, most of them living over five days. Those who died early showed usually the symptoms of bulbar paralysis in addition. Those dying after the lapse of two or three days do so usually as the result of pulmonary or meningitic complications.

Treatment of Middle Meningeal Hemorrhage.—There is no treatment of middle meningeal hemorrhage save by operation. "Trephine; and trephine early," said Jacobson;† and that is a good summing up. What remains to be said concerns the details. There are two objects to be accomplished by trephining: evacuation of the clot, and hæmostasis. As to the first, it is a fortunate fact that owing to the constant anatomical situation of the middle meningeal artery the position of the effused blood is also fairly constant. Roughly speaking, this situation corresponds to the region extending from the

* Apelt: Mittheil. a. d. Grenzgeb. d. Med. u. Chir., Bd. xvi., No. 2, 1906.—Enderlen: Centr. Zeit. f. Chir., 1907.

† Jacobson: Guy's Hosp. Rep., 1885, vol. xliii., p. 147.

external angular process in front to the external auditory meatus behind, and from the zygoma below to the parietal eminence above. A trephine placed more or less in the middle of this region, under the belly of the temporal muscle, will expose the clot nearly always either at its middle or at its periphery. A clot is thus easily evacuated; and, if that were the whole question, but little more would have to be said.

There remains, however, the necessity of securing hæmostasis in case, upon the relief of pressure from the clot, the vessel should continue to bleed. And this question of hæmostasis, implying as it does the endeavor, under surgical principles, to ligate the artery in its continuity, has led to numerous researches upon the exact surgical anatomy of the vessel. Vogt, Witherle, Jacobson, Kroenlein, Steiner, Plummer—to mention only the chief—have all contributed articles bearing upon this question, each trying to determine with the greatest possible accuracy the course of the various branches of the artery, in order that by the removal of a small trephine button one may be sure of exposing the principal branches of the artery. It is evident that in these days, when the principle of large openings and free access obtains, such researches have less interest and importance for us than formerly. Nevertheless, the knowledge is useful as representing most accurately the approximate site of the bleeding point, when a diagnosis can be made as to which branch is ruptured and on which side. Such a diagnosis, however, is frequently impossible; and where possible, it is so often necessary to enlarge the opening freely for the proper evacuation of the clot, that, taking it by and large, the most reasonable procedure is probably to trephine, according to Cushing's recommendation, underneath the temporal muscle, and to do it preferably by Cushing's intermuscular method. This, in the majority of instances, will expose certainly the trunk of the artery, or at least the two branches, before they separate widely.

The methods of localization above mentioned are still worth recalling. (See Steiner's figure, Fig. 37, on page 178.) Their objective point is chiefly the course of the artery, in particular the anterior or the posterior branch, rather than the centre of the clot. According to Vogt, a trephine placed a thumb's breadth behind the external angular process and two fingers' breadth above the zygoma will expose the anterior branch. Witherle's point lies one inch and a half behind the external angular process and one inch above the zygoma. Kroenlein gives two points for trephining, for the anterior and posterior branches respectively. According to his measurements, the anterior branch of the middle meningeal will be found on Kroenlein's upper horizontal, 3 to 4 cm. behind the external angular process; the posterior branch, at the point of intersection of this line with the posterior vertical one, passing immediately behind the mastoid process. (See Fig. 110.) Steiner's directions* are as follows: Draw a line from the middle of the glabella to the tip of the mastoid;

* Steiner: Arch. f. klin. Chir., 1894, Bd. xlviii., p. 101.

bisect, and from this point erect a perpendicular; at the point where this perpendicular strikes another line which runs from the middle of the glabella horizontally around the skull, are found the artery and incidentally the antero-inferior angle of the parietal bone. For the posterior branch Steiner's point lies at the intersection of his horizontal line with a perpendicular passing through the anterior border of the mastoid.

It is advisable to enlarge the opening, unless it be found that the whole clot may easily be evacuated through the trephine opening as first made. A large opening has the advantage of giving better access to a large clot, and of affording some measure of decompression. This last may be a valuable factor in reducing the danger from compression resulting from the very frequent coincident intradural hemorrhage and from the cerebral œdema that so often develops on the second or third day. The consequent defect in the skull is to be considered of minor importance in comparison with the necessity of thorough relief of compression; and particularly so because, when one does an intermuscular operation, the muscle later affords sufficient protection.

A large osteoplastic flap, such as is employed in the Hartley-Krause operation for the removal of the Gasserian ganglion, has been advised by some. The objection to this is that it is a mode of exposure which is unnecessarily extensive, and is therefore apt to make too big a claim upon the patient's stock of resistance, a stock that is often already much reduced.

If the clot is not found upon removing the trephine button, one should separate the dura carefully in several directions with a flat instrument, and in this way one will frequently come upon the periphery of a hemorrhage at no great distance anteriorly or posteriorly. This failing, one should trephine over the posterior point of election (Kroenlein, Steiner). Kroenlein saw one of his patients with a posterior clot die as the result of the omission of this procedure. If the clot still be not found, and if through the trephine opening the dura be found to bulge prominently and appear bluish, and if there be no pulsation of the brain at this point, it is justifiable to open the dura mater. One will do this without hesitation on the right side where one comes down upon the temporo-sphenoidal lobe, which is "silent": on the left, where the corresponding lobe is possessed of very important functions connected with speech, one would hesitate somewhat. Here it would be better first to open the dura over but a small extent. If one then found fluid or blood, it would be necessary to open widely and evacuate it freely. One should try, however, in such a case to have the opening as low in the temporal region as possible, inasmuch as the special functions of this region belong principally to the superior convolution; this is an added reason, in most cases, for going in after Cushing's fashion, low down in the temporal region.

It may happen that, after all, no clot will be found. Under these circumstances it is necessary to consider the advisability of trephining on the opposite side. First of all, one may have operated upon very slight evidence; again, there may clearly have been a mistake in diagnosis; and in the third place, there may be present that rare condition of a homolateral hemiplegia due to lack of pyramidal decussation. It is therefore, as it seems to me, justifiable under such conditions to trephine also upon the other side. Striking examples of the wisdom of this have been published: as, for instance, by Enderlen (*Deut. Zeit. für Chir.*, 1907: "Ein Beitrag zum traumatischen extraduralen Hämatom"). On the other hand, those cases in which, at the post-mortem examination, a large clot is found on the side opposite to that of operation, furnish no less striking a warning.

Certainly it is easy in the case of these patients to operate too much. In many life is hanging in the balance; and the shock consequent upon the wound to the sensory nerves, the loss of blood from the scalp, and the use of the anæsthetic, may be sufficient to paralyze a vasomotor centre that is already working up to its limit. It is folly to say, as is so often said, that "operation at least can do no harm." I have seen a patient go under operation with a slow, strong pulse and all other signs of effectual compensation, and come out of it with a small, rapid pulse, falling blood pressure, and all the signs of failure of compensation, a result which I could attribute to nothing else than the immediate effect of the procedure. Yet, on the other hand, it is a sore sight to see on the autopsy table revealed the clot, clearly the direct and chief cause of death, the removal of which might have saved the patient if the surgeon had had the courage to go ahead upon the other side. And such cases are by no means rare, inasmuch as symptoms are so frequently masked by concussion, and consequently timely diagnosis is impossible. These patients need good surgical judgment and all the refinements of neurological diagnosis.

With middle meningeal clot is seen very frequently, in cases that come to a post-mortem examination, the coincidence of intradural hemorrhage and cerebral laceration, with or without intracerebral clot; in the writer's series of 50 cranial fractures, this condition was found 14 times. The clot being found, however, it should be gently removed with a blunt curette aided by a stream of warm water. When bleeding is finally stopped, the wound should be closed completely, save for one or two cigarette drains placed in the trephine opening; and these should be removed at the end of a day. However, increase in blood pressure might give rise to secondary hemorrhage; therefore, the vessel should be closed at once, if otherwise justifiable. If bleeding continue, an effort should first be made to discover its source by gently pressing the dura and brain aside with a spatula and by careful sponging. If the general direction from which the blood is coming is seen, but the bleeding point cannot be exposed, it will often be advisable to pack firmly with gauze. Many protest, however, that the degree of packing necessary to stop bleeding is liable to keep up undue cerebral pressure. Whenever the point of rupture can be exposed, it is proper to ligate the artery with catgut on a sharp needle. A small tampon pressed into place by forcipressure, or grasping the border of the bone and the tampon together, may fail. If the artery be torn in the foramen spinosum, and packing fail to control it, one should ligate the external carotid. Shepherd, of Montreal, was able in this way to save life.

Symptoms of Intradural Hemorrhage.—One would expect the results of blood extravasation inside the skull, whether inside or outside the dura, to be more or less uniform, inasmuch as it is, after all, chiefly a question of the diminution of cranial space. Yet there is room for much variation. While the extradural clot is fairly uniform in situation and in its effects, intradural hemorrhages vary widely in both these respects. From a consideration of the pathological anatomy (see above) and an analysis of the published cases, together with those of the Royal Victoria and Montreal General hospitals, I have felt justified in suggesting three chief classes of intradural hemorrhage, which all possess some measure of individuality, although they may merge into each other or be coincidently present in any one case.

Briefly, these classes are: (1) Those of the thin sheet clot in the pia-arachnoid; (2) those which are due to the rupture of a larger vein and in which the blood breaks through the arachnoid and lies more or less free in the intradural space; and (3) those which, becoming localized in either of these situations, increase by the addition of serous or cerebro-spinal fluid to the formation of a hemorrhagic cyst. The second group is further subdivided into those of moderate and those of extreme severity. In the former the blood is not too large in amount and shows often a slight tendency to localization, though often, too, it lies quite free at the base; in the latter the violence has been great, the hemorrhage is large, the blood is mainly collected at the base, and the concussion effects are profound. In the main, such a classification can be followed out in the symptomatology. In the first group, symptoms referable to the hemorrhage are very frequently quite absent. Only when this small effusion in the meshes of the pia-arachnoid occupies a position over the motor centres may we get corresponding motor symptoms. In a case reported by Putnam, such a clot excited persistent epileptiform convulsions which ultimately proved so exhausting, in the feeble condition of his patient, as to lead to death. Ordinarily the symptoms are limited to headache of varying degree, persisting even after the effects of concussion and of the usual slight cerebral œdema have passed off. And it is evident that, of itself, such an amount of blood-clot can never cause symptoms of bulbar compression unless it be situated directly upon the medulla or in the fourth ventricle. Symptoms of this nature form an almost constant accompaniment of the severer cases of the other classes.

The symptoms of the third class are practically identical with those of extradural clot, although they come on much later and more slowly, so much so that they sometimes simulate those of a rapidly growing tumor or an abscess. According to their situation, they will cause differing local symptoms. The following is an instructive case in this connection:

A patient, a man 43 years of age, fell from a haymow upon his head, and was unconscious for half an hour, but was able to work on the following day. He was quite free from symptoms, beyond a slight headache, for nearly four weeks. During the second month there gradually developed vomiting, dizziness, and increased headache; but it was not until the middle of the eighth week that he gave up work. He then, in the course of four or five days, became drowsy to the point of stupor; developed a paralysis, first of the arm and then of the leg on the right side; his slow pulse went down to 40, and respirations became vaguely Cheyne-Stokes in type. Admitted to hospital at the end of the eighth week, he was found to be quite unconscious, with typical Cheyne-Stokes breathing, a high-tension pulse of 60, and a blood pressure of 200 mm. Hg, which, however, before operation dropped to 160 mm. In spite of the absence of any history of compound fracture of the skull or of any other possible entrance for infection, a probable diagnosis of abscess was made, especially as he was said to have had for the previous two or three days great difficulty in speech. It was supposed to have originated in the left posterior frontal region, spreading backward. The patient was immediately trephined over the left posterior frontal region, about on the level of the arm centres of the motor cortex. The dura being opened, one came upon the wall of a cyst of dark reddish color and 1 or 2 mm. thick. This being incised gave issue to approximately six or eight ounces of thin brownish fluid in which floated shreds of blood-clot. The cavity, as measured by a lead probe, extended four inches antero-posteriorly; three inches from vertex toward base over the convexity; and two inches in depth from the wound surface. The brain covered by the pia with its vessels lay at the bottom of the cavity. The dura was excised and the wound closed without drainage. Consciousness returned within a few hours. The paralysis largely disappeared within a few days, and the man made an uneventful recovery.

Kroenlein (*Arch. f. klin. Chir.*, Bd. LXXXI., p. 24) reports one case in which he made the diagnosis before operation. The signs of focal compression appeared on the sixth day, and of bulbar compression on the eleventh day, when Kroenlein operated; the patient recovered.

The literature of "subdural hemorrhage" is made up far more of cases resembling this one (though rarely is the free interval so long), of cases, namely, in which the effused blood has become so localized as to form practically a blood-cyst, than it is of those in which the blood is free in the intradural spaces. As is evident, the symptoms are those of focal compression, to which are added, if the clot become large enough, those of general compression. Practically all the cases hitherto reported (M. Allen Starr, Brion, Scudder and Lund, Bowen) under the rubric of "subdural hemorrhage" showed these focal signs, usually motor, and most of them were operated on or came to post-mortem examination under a diagnosis of extradural hemorrhage. The operative results in such cases have been brilliant; far better, indeed, than those of extradural hemorrhage; but surgical literature has taken but very little cognizance of the more severe cases (our second group), which, because the blood is free at the base and gives insufficient focal signs, have in the past not been operated on, and have recovered with difficulty, or not at all. It is of the greatest importance, whenever this can be done, to recognize the true nature of these cases, because so many of the patients die of compression, or, surviving, become the victims of "late effects," without an effort being put forth to relieve them, simply for the lack of focal signs. Too often, in the surgeon's mind, the indication for trephining is lacking—*i.e.*, there are no motor symptoms. For the future such narrow limits cannot be maintained, if life is to be saved. We know that the very absence of focal signs will frequently point to the base as the situation of the hemorrhage, if we can only diagnose the fact of hemorrhage as distinguished from pure concussion with or without cerebral laceration. Under such circumstances our most certain indication of the presence of effused blood must lie in the signs of general compression.

In the second class, therefore, it becomes an important question to determine whether the effusion and the consequent space diminution inside the skull call forth with any regularity the major signs of compression; that is, the slowed pulse, high blood pressure, and respiratory changes representing bulbar anæmia. It is certain that in many cases the picture of concussion merges into that of the paralytic stage of compression without any such reactionary symptoms on the part of the bulb. Such patients die within a few hours at the most. In others, however, that live longer, it is possible to find, in perhaps three-fourths of the cases, according to the writer's analysis, a slowed pulse, a stertorous or Cheyne-Stokes respiration, and presumably, although hitherto manometric observations are largely lacking, a rise in blood pressure. In still others these too are absent, as in the following case report, which illustrates a combination of the extensive pial sheet clot and the large free basal hemorrhage, neither producing any sufficient signs of localization, nor the signs of compression, either general or local, save that of uninterrupted unconsciousness:

R. V. H. Surgical Case Reports, No. 7,926 (Dr. Bell's Service): The patient had been struck at noon by a street-car; he was picked up unconscious and was brought to the hospital within fifteen minutes of the accident. *Status on admission:* Unconscious, T. 96° F.; P. 80; R. 24; eyes directed to the right; pupils contracted equally, no pupillary reflex, corneal absent; no hemorrhage evident from any of the orifices, but two ounces of bright red blood vomited; muscles generally flaccid; no localizing signs. Within twelve hours the temperature had risen to 102.3° F., the pulse to 120, and respiration to 40. On the next day, fever varied from 101.2° to 102.3° F.; the pulse-rate from 140 to 153, and respiration from 30 to 36. On the second day respirations became somewhat difficult and noisy; râles were found in the chest; and the patient was unable to swallow. On the third day the temperature shot up to 104.4° F., respirations to 48; the pulse became still more rapid and feeble, and the patient died seventy-two hours after the injury, without ever having regained consciousness or shown any definite localizing sign. At autopsy there was found a depressed fracture of the skull in the middle line 2 cm. behind the bregma, with very extensive effusion of blood in a thin flat layer in and under the meshes of the pia-arachnoid over nearly the whole surface of the brain. In addition there was a large clot, evidently dating from the time of injury, not just before death, and occupying the greater part of the base anteriorly, leading to "leptomeningitis and encephalitis" with erosion of brain substance. There was also a marked inhalation pneumonia with old purulent bronchitis, to which, doubtless, death was more directly due than to the cerebral compression.

In the less severe cases of Class II. the blood may be either at the base or over the convexity. With the blood at the base there will be more or less prolonged disturbance of consciousness, from stupor to coma, with headache, usually severe, and with perhaps some slowing of the pulse and some rise in blood pressure, but often without focal signs of any sort. The symptoms are not alarming, and it is easily seen that they will disappear without interference. This they usually do, but slowly, and often imperfectly. With the blood over the convexity there will be the focal signs proper to the cortical area over which the blood happens to lie—motor, sensory, aphasic, or visual; but these rarely appear on the first or second day. If they appear later and come on slowly, the case belongs rather to the third group.

The Coincidence of Concussion or Contusion with Compression from Hemorrhage.—Pathologically, this coincidence is often seen, and Plate XXXIII offers a good illustration. Clinically, the main question relates to the combined effect on the bulbar centres. The question as to whether a possible focal lesion, whether motor or other, is due to contusion or laceration or to hemorrhage can be settled only by the time of onset of the focal lesion: if immediate, it is contusion: if delayed, it is more probably hemorrhage. A more important point, however, concerns the effect upon the vital centres in the medulla.

If the concussion be severe, hemorrhage may be of large size and doubtless be a strong factor in causing death, yet fail to produce the typical signs of the compression which it is exercising on the bulbar centres. As yet I find no study of a series of cases with regard to this point. The clinical condition of concussion as complicated by compression from intracranial bleeding has need of careful consideration, especially with the help of a clinical blood-pressure apparatus. The essential difficulty, in the writer's experience, lies in the apparent fact that a concussion which is severe enough to cause marked shock-like symptoms will by that very fact prevent or mask more or less completely the bulbar symptoms of compression which one would otherwise expect from a coincident hemorrhage of any size. In the presence of such a hemorrhage the less the concussion the clearer are the signs of compression; the greater the concussion the more are these signs absent and the greater is the likelihood of death as foreshadowed in the picture of shock.

Diagnosis of Intradural Hemorrhage.—In many of the severe cases, as with extradural hemorrhage, diagnosis is impossible, as the patient dies shortly of concussion, and coma is so profound. In cases of less severity, those in which the patient lives for any material time, and yet in whom unconsciousness is uninterrupted from the first, the diagnosis has to be made between concussion with hemorrhage and concussion without hemorrhage. If fracture be present and bleeding has occurred from any of the associated orifices, it may with reasonable certainty be concluded that intradural hemorrhage is also present. But in the absence of this, our only guide is the development of symptoms of compression. In the case of possible localizing symptoms, chiefly, of course, referable to the motor area or to cranial nerves, it must be established, for these to be of value, whether they occurred immediately after the accident or only after some time. In the former case they may be due to laceration of the brain without hemorrhage; in the latter, only to hemorrhage or possibly œdema. Such a distinction will often be impossible, if they are already present at the first observation. But it is not rare for such to develop under the eye of the observer, and then they indicate hemorrhage very clearly. Even then one has to distinguish between a cortical and a subcortical situation of the blood; this distinction will be discussed in another section. (See page 260.)

Frequently, however, the greater part of the blood is at the base, and causes no clear signs of localization. In such cases one has to search for the signs of general compression—slow pulse, arrhythmical breathing, and a high blood pressure, with profound unconsciousness. To expect such a full-fledged picture of general compression in these cases, as is seen in experiment or in many cases of middle meningeal hemorrhage, would be a mistake. And I have already theorized as to the reason of this, without being yet able to present proof, in saying that the inhibitory effect of concussion upon the bulbar centres interferes with their normal response to the anæmia of compression. Concussion masks compression. The pulse is rather fast than slow, between 80 and 100, the respiration may or may not be stertorous, but is usually increased in rate and is regular, from 26 to 36 or over; the blood pressure, in my experience, may keep around normal, but is more often below it.

Profound unconsciousness is a symptom common to both concussion and compression, and is therefore not available for differential diagnosis. It will nevertheless give a valuable hint if it can be established that it is progressively becoming deeper. The least return, after the trauma, toward consciousness, that is followed by a persisting deeper coma, amounts practically to the evidence of a free interval and has the same diagnostic significance. The necessity of fine observation in detecting the less clear changes in respiratory rhythm or depth, not amounting to Cheyne-Stokes phenomenon, or variations in the rate of the pulse, or in the height of the blood pressure, or in the depth of unconsciousness, rhythmical variations in the size of the pupils—everything which, in short, points to that wave-like response on the part of the vasomotor centre which we have learned to recognize as its struggle against the anæmia of compression—the necessity of the keen eye for all these things is very great. They may be present when the grosser changes, such as high blood pressure, Cheyne-Stokes breathing, and a slowed pulse, are absent.

The differential diagnosis from extradural hemorrhage has already been discussed. It may be pointed out that it is chiefly those cases which belong to Class 3, and in which the blood becomes more or less localized, that lead to confusion.

The final decision is nowadays commonly made by lumbar puncture. This is important enough to receive separate consideration.

Lumbar Puncture in the Diagnosis of Meningeal Hemorrhage.—While this procedure was used as early as 1895 by Fuerbringer in the diagnosis of two cases of cerebral hemorrhage, it was not until 1901 that it was employed in traumatic cases; and at first it was applied more particularly as an aid to the diagnosis of cranial fracture. Tuffier and Milian, finding blood in the puncture fluid of a case of fracture of the skull, put forth the fact as being diagnostic of fracture. We now know that it is diagnostic only of intradural bleeding, whether with or without fracture. Since that time numerous communications have been made upon the subject, chiefly by the French, and particularly by Tuffier, Poirier, Guinard, Rochard, Potherat, Quénu, and others. There is remarkably little to be found on the matter in English and American literature, although doubtless its value is recognized and practised in most surgical hospital services. Lavallée has lately collected twenty-four cases from the literature, including three unpublished ones, in a Paris thesis.

There is no need to go into the technique of lumbar puncture beyond saying that it is necessary to collect the fluid in three small tubes. By this measure we distinguish between blood present in the cerebro-spinal fluid and blood effused from the accidental puncture of a vessel by the exploring needle. In the latter instance the blood is apt to be pure or nearly pure, and there are only a few drops of it, which are found in the first tube; while in the second and third tubes is the cerebro-spinal fluid. If there has occurred bleeding into the intradural or subarachnoid space in the cranium and it is evacuated through the lumbar route, the fluid will be uniformly tinged and will be the same in all three tubes. The blood in the former case coagulates, while in the latter, being held in an isotonic solution, it does not. The experience in Montreal is strongly in favor of the diagnostic certainty of the test. If the blood is thus found to belong to the subarachnoid space, presumably of the cranium, it is evident that it may originally have been effused either between the dura and the arachnoid or in the subarachnoid space, or primarily in the cerebrum, with subsequent outbreak into the meninges or into the ventricles. If the bleeding has been primarily into the extradural space the blood will not appear in the lumbar-puncture fluid unless the dura be simultaneously torn. Naturally the usual cause of the hemorrhage is a basal fracture; yet, in common with many others, I have observed cases in which the bleeding was unaccompanied by fracture. In such it is evidence of no more than meningeal vascular laceration. Ordinarily speaking, the value of the procedure will lie chiefly, first, in establishing the fact of hemorrhage, and, second, in distinguishing with a fair degree of certainty between extra- and intradural origin. Apparently the blood does not find its way to the lumbar region under a few hours. On the other hand, it may disappear entirely from the fluid in a few days. Therefore the puncture must be done neither too soon nor too late. The only point of prognostic value that it gives us is that, according to French authors, the more blood there is in the fluid, the greater is the original hemorrhage, and presumably the more severe is the injury.

Certain precautions are necessary. Lumbar puncture may be by no means innocuous. Fuerbringer, in 1897, sounded a warning note after observing one or two fatalities in cases of intracranial tumor; and other similar cases have been reported since. In the traumatic cases this danger is also present. When one analyzes Lavallée's series of 24 cases, 3 seem to have died very shortly after, and apparently as the result of, the withdrawal of 30 to 40 c.c. of fluid. The writer has also seen, in his own service, a rapidly fatal result under compression signs following the withdrawal of no more than 15 c.c. The French warn against removing more than 25 to 30 c.c., but I think that even this amount is too large if there be present the signs of serious intracranial tension. Death under such circumstances is usually rather sudden. The explanation, in view of the work of Leonard Hill and Cushing, certainly lies in the fact that the medulla is driven down into the foramen magnum by the pressure from above, as soon as the supporting column of lumbar fluid is removed, thus crushing the vital centres in the bulb against the rim of the opening. If, therefore, the sphygmomanometer shows a high arterial pressure, and the pulse is slow, or even in the presence of a low blood pressure, if the patient is in shock, caution must be exercised in doing a lumbar puncture. This is not to say that it should not be done, but that only a very small amount should be removed for diagnosis.

Prognosis of Intradural Hemorrhage.—When one analyzes the cases reported by Bowen, by Brion, and by Scudder and Lund, all of which came to operation or to autopsy, it is evident that they are divisible, pathologically speaking, into two main classes. In one the blood forms a localized collection, which, increasing but slowly in size, becomes only after some days large enough to afford a definite indication for operation, the indication consisting nearly always in signs of pressure on the motor cortex and secondarily on the bulbar centres. In the other, serious symptoms urge to operation or lead to death within the first two or three days; here the blood, it is true, may be largely localized, but more often it is free in the intradural space, and often fills up the basal region. Generally speaking, the cases correspond to our second and third groups. (See page 194.) In some of these operation is curative; but if death occurs, it is due partly, no doubt, to the compression caused by the effused blood, but largely also to the effects of concussion and laceration of the brain itself. We have thus the early class and the late class; and the early class represents the more severe cases. Bowen suggests further a division of the cases according to the severity of the concomitant injury. In Class A are included instances of practically pure compression by blood-clot, there being no reason to suspect (using his own words) that laceration, or even concussion, is present; in Class B, compression is complicated by the presence of laceration, very pronounced contusion, or severe general concussion. These coincident conditions certainly influence considerably, as he says, the course of the cases, and must frequently be regarded as the real cause of death. If one analyze the operated cases of Bowen and of Brion according to these points of view, as in the accompanying tables, one finds certain very interesting things:

Class A.	Recovered.	Died.	Class B.	Recovered.	Died.
Early................	13	1	Early................	5	17
Late.................	44	7	Late.................	5	3

Thus we see that in the cases of slight or moderate injury resulting in an intradural hemorrhage sufficient to exact operation (Class A), 57 recovered and 8 died, and what slight difference there was in the results as between early and late operation is in favor of the early operation. On the other hand, in those complicated by severe cerebral lesions (Class B), 10 recovered and 20 died, but in these there was a marked difference between the early and late cases. Of 22 operated on early, that is, within three days, 5 recovered and 17 died, while of 8 operated on late, after three days, 5 recovered and 3 died. This simply means that with severe injuries the compression of the more rapidly effused blood and the shock effect of concussion and laceration form together such a serious condition as to force to early operation, an operation which is, nevertheless, frequently in vain. In the later operations the patient has survived the early shock, but an intradural hemorrhage has gone on increasing and has necessitated interference. The chances are here much better than in the early operations of Class B, yet very much worse than in the late ones of Class A; the actual amount of compression exercised by the clot in B may be no greater than that in A, yet the brain in the former case has been robbed of its resisting power by the paralyzing effect of the concussion or laceration, and the vital centres are earlier and more certainly exhausted.

It is evident, therefore, that the prognosis of intradural hemorrhage will depend upon two chief factors: First, the degree of cerebral injury; thus, in the 36 cases of Class A (Bowen), 22 recovered and 14 died; in 36 of Class B, 6 recovered and 30 died. In the second place, it depends a great deal upon the amount of blood effused, and especially the rapidity of this effusion. The position of the effused blood also is of importance in that, when situated at the base, near or upon the medulla, it is much more fatal than when over the convexity. Thirdly, it depends upon the question of operation. In Class A, out of the 14 fatal cases, there had been no operation in 11; while of the 22 that recovered, all had been operated on; in Class B, of the 30 deaths, in 11 there had been no operation; of the 6 that recovered, all had been operated on. When one analyzes the post-mortem reports of the 22 patients who died without operation, one finds that in the majority of them there had been present effusions which, technically speaking, might easily have been removed by trephining.

From the point of view of the three classes into which the condition, clinically and pathologically, is divisible, it is evident that in the first the outlook is very good; the sheet clot is usually reabsorbed without causing trouble. In the second, we have, in the main, the condition just discussed. In the third, those of the later developing localized collections, the issue will depend on the size which the effusion attains and on the question of operative relief. In a few the cyst ceases to enlarge, and may then cause persistent paresis, or loss of sensation, or mental defect, etc., according to its situation on the cortex. Or, more frequently, it goes on increasing till it kills the patient by compression, unless relief is afforded by operation.

The Indications for Trephining in Intradural Hemorrhage.—In the first place, the presence or absence of fracture has but little to do with the case. It is the hemorrhage and the damage to the brain itself that determine the question whether or not operative interference should be resorted to. First, in the presence of a depressed fracture, there can nowadays be no question as to the necessity of trephining. In the next place, in the presence of a condition which indicates a localized compression from blood, whether the latter be intra- or extradural, one should trephine. If, however, there be no indication of pressure transmitted to the bulbar centres, the question arises whether, in view of the possible absorption of blood-clot, one should not wait for some days rather than operate as soon as the diagnosis is made.

On the one hand, it must be said that if the symptoms, usually those of motor paralysis, have not come on within a very short time after the injury—not, let us say, till twenty-four to forty-eight hours have passed—it is quite possible that the pressure is exercised, not so much by blood-clot as by a localized collection of serum or cerebro-spinal fluid, or a localized œdema of the brain substance—a condition to which attention has been drawn above. Under such circumstances one may expect the paralysis to disappear within a very few days. Under the opposite circumstances, however, where symptoms have come on very shortly and are persisting, the writer believes that it is important to trephine without delay: in the first place, to prevent the ill effects on the nerve fibres of continued pressure; secondly, to restore consciousness, and by that means to prevent the inhalation pneumonia of which so many unconscious patients die; and, in the third place, to prevent as much as may be possible the ultimate development of meningeal adhesions from organization of the blood-clot and of gliosis in the cortex, which latter has been shown by Koeppen* to follow any material pressure by an intradural clot. If in such cases there be symptoms of pressure on the medulla in addition to those of localized pressure, the indication to trephine becomes absolute, inasmuch as it is a matter of common observation to find that the bulbar centres suddenly give out after a few days' compression, even in the absence of any increase of pressure.

In the next place, there are the cases of pressure from localized intradural hemorrhage which has practically become a hemorrhagic cyst with focal signs. Here the indication for trephining is clear. There is, further, that frequent type of case where the patient remains partly or entirely unconscious and shows signs of a moderate compression of the bulbar centres, but where localizing signs are quite absent. Here there is usually a greater or less quantity of free blood over the basal region—whether with or without sheet clot in the arachnoid or the vertex makes but little difference. These are the cases which are ordinarily let alone under the argument that their prospects of recovery are very good, and that what effusion of blood there may be will be reabsorbed by nature. Some years ago, however, in 1890, Horsley† protested strongly that such patients should be trephined in order to remove as much as possible the chances of organization of the clot and the development of meningeal adhesions. And, lately, Harvey Cushing‡ has expressed himself emphatically in the same sense, and has advised frequent recourse to the intermusculo-temporal operation just above the zygoma, in order best to evacuate blood from the base. He has on several occasions taken for comparison parallel cases in his hospital practice, and the contrast between the operated and the non-operated patients has been very marked. Those operated on were relieved from headache, made an immediate recovery, and in all probability will remain free of those post-traumatic neuroses which have been shown by Spiller, English, and Pearce Bailey to follow so frequently head injuries; in those let alone, headache was persistent and recovery slow.

There remain to be discussed those extremely severe instances of cranial injury in which the patient nearly always dies within the first twelve to twenty-four hours, apparently as the result of a high grade of concussion and extensive laceration of the cerebral substance. Of these there appear to be two classes, according to the presence or absence of signs of reaction on the part of the bulbar centres to the compression of the effused blood, for in practically all

* Koeppen: "Ueber Veränderungen der Hirnrinde unter einem subduralen Hämatom." Arch. f. Psych., xxxiii., p. 596.

† Horsley: Brit. Med. Journal, 1890; Report of German Surgical Congress.

‡ Cushing: N. Y. Med. Jour., Jan. 19th, 26th, Feb. 2d, 1907; Ann. of Surgery, May, 1908.

cases there is a considerable effusion of blood. It is probably a reasonable hope that, in consonance with the advance of our physiological knowledge of blood pressure and the reaction generally of the medullary centres to concussion and compression, we may do more for these unfortunates than has been done in the past. If there are signs that the vagus, respiratory, and vasomotor centres are being stimulated by the compression anæmia of the effused blood, in spite of the shock of the coincident concussion, the indication is clearly a double one—to remove the effused blood which is the source of compression, and to combat the shock effects of concussion. I am unaware that any definite plan of treatment such as is thus indicated has been pushed to its logical conclusion in surgical clinics generally; at least, there is no mention of such in the literature. It seems reasonable, nevertheless, that under such conditions one should immediately resort to stimulants such as strychnia, intravenous infusion of salt solution containing adrenalin, bandaging of the extremities or the use of Crile's pneumatic suit, elevation of the foot of the bed, and such other measures as have proven of value in shock; and at the same time trephining should be done to remove the basal effusion. This operation, I believe, had best be done under complete local anæsthesia with Schleich's solution, even though the patient be unconscious, in order to avoid adding to the shock by the cutting of sensory nerves. Mitchell and Cushing have lately shown that it is quite possible to do a complete cerebral operation without a general anæsthetic even in conscious patients.

In the other event, where the shock effect of concussion predominates and there is no evidence of reaction on the part of the bulbar centres—a condition which Porter* has likened to that of the animal whose vasomotor tone has been cut off by section of the cervical cord—it is clearly unwise to do anything but try to tide the patient over the shock. Artificial respiration, the application of heat, and the various other measures already mentioned are here in place. If a proper reaction is thus obtained, one might immediately, if the bulbar symptoms of compression appear, go on to trephine as above described.

The question of where to trephine in intradural hemorrhage will often be a most difficult one. It must depend chiefly, where localizing symptoms are present, upon the neurological diagnosis, and this with but slight regard to the position of the injury to the scalp. Only when the latter coincides with the bleeding point as indicated by the symptoms should one trephine over the site of the external injury. This will, however, frequently not be present, even in cases where the symptoms of general pressure are marked but localizing symptoms are absent. In such instances it is justifiable to explore the base by trephining underneath the temporal muscle, choosing preferably the right side and using Cushing's muscle-splitting operation. Occasionally one will find in this way an unsuspected extradural hemorrhage. In other cases the blood

* Porter. *Loc cit.* *Vide* section on Concussion.

will be found distending the dura and associated with a lack of all pulsation. Frequently also the dura will be discolored. In any case it is wise to open through it, whereupon, in many cases, liquid or clotted blood, often diluted with serum, will be extruded under pressure. If this measure fails, the surgeon is justified in lifting the temporo-sphenoidal lobe gently, as in this way he may find a collection at the base, the evacuation of which may prove very beneficial. Cushing recommends the insertion of cigarette drains underneath at the base. These drains are led out through the skin incision and removed in the course of forty-eight hours. A considerable area of bone beyond the trephine opening should be removed for the sake of decompression.

Lumbar Puncture in Treatment.—In the first days of lumbar puncture the hope was naturally entertained that the procedure might be of decided therapeutic value. Tuffier expected that it would relieve the compression symptoms of intracranial hemorrhage by decompression. So far as I know, it is only in France that the practical test of this hypothesis has been made. Lavallée in his thesis collected a number of observations in which the measure seemed to be of service; of these the most striking was that of Quénu. (*Bull. Soc. de Chir.*, Oct. 25th, 1905.) In three other cases it seemed to do good, affording appreciable relief of headache in conscious patients some days after the injury. As against these favorable results we find, upon analysis, three cases in which death seemed to be caused, or at least hastened, definitely enough, by the puncture; one in which it actually caused more severe headache and vomiting instead of relieving these symptoms; and fourteen in which no effect whatever was obtained. In two of these last the patient had to be trephined later for subdural clot causing localizing symptoms. It would certainly seem impossible to draw away any material amount of blood from the cranial space in this way. However, its value in relieving headache when there is no material increase, clinically speaking, in intracranial tension, when the patient is conscious or nearly so,—in short, in cases of concussion, with but slight hemorrhage,—is such that the procedure is allowable. In any case, not over 20 to 30 c.c. should be removed. If the patient is comatose, the procedure should never be employed therapeutically, but only for diagnosis.

VIII. INJURIES OF THE VENOUS SINUSES.

Of the anatomical position of the sinuses, the accompanying illustrations (Plates XXXI and XXXIV) give a fair conception. Wounds of the minor sinuses, so far as we know, are comparatively rare. Indeed, it is somewhat surprising, when one considers the frequency of basal fracture, that the basal sinuses, the inferior petrosal and the basilar, for instance, are not more often torn. However this may be, the sinuses of every-day surgical interest are only three: the longitudinal; the lateral, including, of course, their junction in the torcular; and the cavernous. Of these, the injury of the longitudinal carries with it least danger; its lumen, indeed, for the first four inches of its course from the crista galli, is so small that a tear in that part is said to be unimportant. The torcular corresponds with fair exactness to the external occipital protuberance. The lateral sinus takes a course which follows a line drawn from this part to the zygomatic arch as far as the posterior border of the mastoid process, at which point it bends downward into the sigmoid sinus. The anatomical relations of these and of the cavernous sinus are well seen in Plates XXXI, XXXII, and XXXIII. The injuries of all three usually lead to effusion inside the dura, though often also outside it, and as such are included in the general consideration of intracranial bleeding. A wound, however, of the cavernous sinus may occasionally, by implication of the carotid, lead to the formation of an arterio-venous aneurism, a condition which frequently goes under the name of exophthalmos pulsans, and is worthy of separate consideration.

Exophthalmos Pulsans.—The term "pulsating exophthalmos" indicates a symptom complex which of late years has generally been thought of as being identical with the arterio-venous aneurism involving the internal carotid artery and the cavernous sinus. The identity, however, is not justified; in fact, it is only in about one-third of the cases that arterio-venous anastomosis occurs, at least so far as can be judged from the autopsies published. The term, therefore, represents simply a condition of variable etiology, and should consequently not be dignified with the title of a disease entity. Wilder, in 1897, analyzed 24 autopsies, all previous to the year 1890, and found (I quote here from Ransohoff) that there was a traumatic or spontaneous rupture of the internal carotid within the sinus in 7. In 4 there was an aneurismal dilatation of the artery without rupture. In 6 clinically characteristic cases, no lesion of the carotid was found. In 1 there was an aneurism of the ophthalmic. In 4 cases vascular retrobulbar tumors were found, and in 2 of these the growths came from within the skull cavity. These pathological data may be taken as representing fairly enough the etiology of the condition of pulsating exophthalmos. In this place there will be considered only that aspect of the subject which is concerned with arterio-venous aneurism as a cause.

As early as 1809 this was recognized by Travers, who entitled it "A Case of Aneurysm by Anastomosis in the Orbit, Cured by the Ligature of the Common Carotid Artery." Dalrymple showed before the Royal Society of London, in 1812, a second case. A traumatic origin for this anastomosis has been found in about sixty per cent of cases. The trauma is usually a bursting fracture passing through the base and involving the artery and vein as they run in their common dural sheath opposite the sella turcica. A typical instance is described by Harvey Cushing, whose patient had his head crushed between the side of a ship and a buttress. In Ransohoff's case the condition followed a light blow over the right temple, which did not cause even unconsciousness. Occasionally the violence is a direct one, usually a punctured fracture through the orbit.

SYMPTOMS.—The cardinal signs are naturally those of pulsation and of protrusion of the eyeball. This condition, curiously enough, makes its appearance not shortly after the injury, but usually days, weeks, or even months afterward. It is perhaps allowable to suppose that its appearance coincides with the establishment of a reversed circulation through the ophthalmic and orbital veins, by which the pulsation of the internal carotid artery is transmitted in a reversed direction throughout the peripheral territory. Carrel has shown that, in the limbs, such a reversal leads to the thickening or so-called arterialization of the walls of the anastomosed veins. However this may be, some time after the accident the eyeball is gradually forced forward, the upper lid being tense and swollen and the conjunctiva more or less inflamed, and there appears pulsation either in the eyeball or in the peribulbar tissues, particularly above and to the inner side at the inner angle. If the pulsation is not visible on mere inspection, it may be palpable, or at least be brought out by slight pressure upon the eyeball backward. The veins of the eyelid are large and pulsate; those of the optic disc are likewise enlarged and often pulsating. The external rectus is usually paralyzed, probably from pressure upon the sixth nerve in the external wall of the cavernous sinus. Upon ophthalmoscopic examination there is usually found some degree of swelling of the disc, which may go on to atrophy, so that in many cases vision is either quite lost or largely so.

Apart from these objective signs there are usually very troublesome subjective ones, consisting in severe headache, and, above all, loud noises, variously described as buzzing, humming, sawing, inside the cranium. This may be so loud as to render the patient quite deaf to external sounds. Upon examination with the stethoscope, a loud bruit is often discovered over the eye, sometimes over the entire head. Nosebleed may occur frequently. In rare instances the condition is bilateral, probably through arterialization of the veins of the other eye by way of the circular sinus.

TREATMENT.—While various conservative methods have been advocated, such as continuous compression of the carotid, the treatment has for long been practically confined to the operative ligation of the common carotid artery. Travers, by this method, was able to cure the first case recorded, and since then no other method of treatment has been materially effective. Sattler, whose series is the largest yet analyzed, found that in 56 pure cases of arteriovenous aneurism, ligation of the common carotid accomplished 37 cures; in 11 there was failure, and in 8 death ensued. Ransohoff refers to the figures of Vodon, who in 1899 had collected 58 traumatic cases in which the common carotid of one side had been tied. Of these 46 per cent were cured, 35 per cent improved, 10 per cent unimproved, and 10 per cent died. Ransohoff himself collected the reports of 21 cases published after the period of Vodon's figures. Of these 14 were cured, 5 improved, and 2 ended fatally—1 of these, however, from cerebral abscess. He found also in the literature 8 cases in which both common carotids were tied; 6 of these recovered, 1 was followed by recurrence, and 1 died. From these figures it is evident that the only rational treatment of this condition is the ligature of the common carotid; and that in spite of the not altogether infrequent failures to prevent recurrence. Considering the comparative freedom of anastomosis by way of the superior thyroids from the external carotid, it is rather to be wondered at that failures are not more frequent. In some cases (Ransohoff) the external carotid and superior thyroid arteries have been ligated as well as the common, to prevènt this collateral circulation. The danger of unilateral anæmia of the cerebrum, which is already quite appreciable in ligation of one common carotid alone, is possibly somewhat increased by the addition of this procedure. Such a risk, however, must be really accepted as part of the bargain in these patients whose lives are rendered miserable by the deformity and the serious subjective symptoms so frequently present.

Travers: A Case of Aneurysm by Anastomosis in the Orbit, Cured by Ligature of the Common Carotid Artery, presented to the Royal Medical and Chirurgical Society of London, 1809.

Léon LeFort: Revue de Chirurgie, 1890, p. 369.

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Ransohoff: Surgery, Gynæcology, and Obstetrics. August, 1906 (with Bibliography).

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IX. INTRACRANIAL HEMORRHAGES IN THE NEW-BORN.

Till lately the intracranial hemorrhages of the new-born, at present one of the most important of the newer lines of work in neurological surgery, excited no more than pathological interest. Obstetricians were concerned with the possibility of their diagnosis *intra vitam,* but without the idea of possible surgical relief; and neurologists thought of them merely as being the commonest cause of the spastic paralyses of childhood. To Cushing, in 1904, belongs the credit of having first demonstrated the possibility and the advantage of removing the effused blood by surgical means, although, in 1901, Keen had suggested and urged the necessity of operative interference. Hitherto in recorded literature I can find but one other report of operation for this condition, the case, namely, of Seitz.

General Considerations.—It is naturally difficult to determine the actual frequency of meningeal hemorrhages at birth, inasmuch as there can be small doubt but that many small effusions are reabsorbed without causing symptoms, either immediate or remote. In post-mortem examinations on infants that are still-born or have died within the first few days, it is extremely common to find sheet extravasations in the meshes of the pia-arachnoid; and there can be little doubt but that they were the direct cause of death. In an analysis of 74 autopsies upon such infants (by Drs. McCrae and Klotz at the Royal Victoria Hospital), I found intermeningeal hemorrhage in 32, in 19 of which it was of considerable extent; and in 5 others there was extradural hemorrhage. In exactly how many of these cases death was due to the hemorrhage it was very difficult to say; yet in many of them it seemed to be the direct cause. The very considerable number of children suffering from the various forms of Little's disease, epilepsy, and the various grades of mental deficiency, all traceable to such birth hemorrhages, indicates, from another side, their frequency.

The situation of the clot is nearly always intradural. It may be held in the meshes of the pia-arachnoid in which it is apt to spread widely; or, breaking through this membrane, it may be found more or less free in the intradural space. According to Seitz and Cushing, it is situated over the convexity of the hemispheres, and the thickest part of the clot is usually the highest, indicating a usual origin in the rupture of a cerebral vein not far from its entrance into the longitudinal sinus. In my series I found the convexity of the brain involved in 20; in 6 it is specifically mentioned that the clot lay near the longitudinal sinus; in 9 the blood was situated chiefly at the base, and in 4 of these in the posterior fossa; in 3 the whole surface of the brain, both convexity and base, was covered by effused blood; in 6 one hemisphere was alone involved, in 4 both hemispheres; in 5 the clot was extradural as well as intradural. All of these last five were still-born, save one which lived five hours. In only two or three was effused blood found inside the cerebral substance.

These facts have some importance with reference to the question as to whether to trephine at all; and, if so, how widely. No doubt, in the majority of cases, the hemorrhage is near the longitudinal sinus, and this corresponds with the greater frequency of the involvement of the legs in the spastic paralyses of later childhood. In the majority also the clot lies over or near the motor tract, and this is comprehensible when one remembers that it is chiefly in this region that the cerebral veins are grouped together in their entrance into the longitudinal sinus.

Etiology.—Two factors combine doubtless to cause these hemorrhages, both to a certain extent of a mechanical nature. In the first place, during birth, there must be a considerable degree of stagnation in the cerebral veins: on the one hand, from the pressure of the uterus upon the placenta during labor pains, and on the other from the asphyxia incidental to prolonged labor. Again, and this is probably, according to Kundrat, Seitz, and Cushing, the chief factor, the overlapping of the parietal bones upon each other during the moulding process of delivery is apt to pull in a particular way upon the cerebral veins as they cross from the topmost convolution to the lacunæ laterales of the longitudinal sinus, a point at which they become more or less unsupported. That extreme passive congestion alone may cause rupture of the smaller vessels has been shown by Kredel, and is seen also in the hemorrhages coming on during whooping-cough.

Symptoms.—A most complete analysis of symptoms has been made by Seitz upon the basis of 19 cases. Such patients may be divided roughly into two classes: (i) Those who, as he says, "die away" within a few hours after birth, in whom autopsy reveals serious lesion of the brain substance as well as of the vessels; (ii) those who survive the first few hours, in whom clear signs of pressure appear. These again may be born asphyxiated (of 13 cases 11) or else apparently normal (of 13 cases 2). The "blue baby," born asphyxiated, is liable, *ipso facto,* to have some pial hemorrhage and must be particularly watched. Ordinarily, of course, it for the time, under proper care, recovers normal appearance, as it is always a vein that is torn and venous pressure is low. Further, the infant's brain being, in its non-medullated state, very tolerant of a diminution of space, it naturally requires the effusion of a considerable amount of blood before serious symptoms of compression appear. Thus we see that it is frequently not till two or more days have elapsed that such signs do appear. They are at first irritative in character; the baby is very restless, cries a great deal, and is either disinclined or unable to nurse. If the finger is put in its mouth there is excited no sucking reflex; it looks abnormally pale, rarely does it vomit; the fontanelle becomes tense, and pulsation in it in the later stages may quite disappear. There is a great increase in the reflex excitability of the child, slight jars will initiate aimless movements of the limbs. Exceptionally, however, the baby will lie abnormally still, and these, Seitz believes, have chiefly infratentorial hemorrhage. Fever is not uncommon. As the condition gets worse, pallor gives way to cyanosis, and signs referable to the bulbar centres appear. Of the cardinal signs of slow pulse, irregular respiration, and high blood pressure, the latter is perhaps the most constant; in fact, slowing of the pulse is very frequently lacking. The rise in blood pressure, however, is seen in strength and fulness of the pulse, and in an accentuated aortic second sound. Respirations are usually deep and slow, occasionally intermittent, yet often they become quick and shallow. The slow, stertorous respiration of adults is not seen. These variations doubtless depend upon the degree and location of pressure. The veins over the skull, the eyelids, and, according to Cushing, in the optic discs become dilated. The pupils are frequently unequal. As to the motor symptoms they consist ordinarily in irregular convulsive movements indicating rather cortical irritation than its paralysis. These are most often generalized, but in the later days may become unilateral. It must be remembered, of course, that the clot is almost as frequently bilateral as unilateral. In fact, actual paralysis rarely, if ever, develops.

Diagnosis.—When one discusses this question with obstetricians, it is somewhat remarkable to find that they consider the diagnosis extremely difficult, and this seems to be their main objection to operative interference. The writer has yet no personal experience in the matter, but it would seem, from the observations of Seitz, Cushing, and a few others, that the diagnosis should not be especially difficult, certainly not in the marked cases of pressure. Yet the difficulty of the diagnosis is often certainly sufficient to make welcome any procedure that promises certain information; and it would seem that lumbar puncture, so valuable in the diagnosis of meningeal hemorrhage in the adult, gives equally certain results in the infant. Devraigne was the first (in April, 1904) to demonstrate its feasibility and usefulness; and Dutraix has lately written a thesis on the question. (Devraigne: *La Presse méd.*, Paris, Aug. 16th, 1905; Dutraix: Thèse, Paris, 1905.) In the matter of technique, a hypodermic syringe with a large-sized hypodermic needle is sufficiently large for infants, but the lumen should be cleaned out with a wire while it is in position, lest it become clogged with blood. As with the adult, one should enter the canal on the level of the iliac crests; and the space is entered at the depth of from 13 to 15 mm. The subject certainly possesses a live interest for the general practitioner. It is he who sees these cases first, and it is he who must be alive to their importance, especially the importance of making a correct diagnosis. The method can be carried out with ease. It is only necessary to take the same precautions as one does with adults, inasmuch as there are probably the same dangers to be feared.

While the diagnosis of mere meningeal hemorrhage is not over-difficult and can be settled usually by lumbar puncture, the determination of the situation of the clot, whether on one side or the other or possibly on both sides, whether over the vertex or at the base, seems to be rather difficult. The twitchings are frequently not unilateral, nor can a difference in the size of the pupils be of much value. In such cases it may be necessary to explore on both sides. In some, however, convulsive movements are from the first unilateral or become so later, and in such the diagnosis is clear.

Prognosis.—Of the 19 infants observed by Seitz, in whom convulsions and the signs of general pressure appeared, only four survived. Of these four, one died afterward, and another acquired nystagmus and athetosis and was probably imbecile. The outlook with operation seems to be much better than under the expectant treatment. Of Cushing's nine cases five were fatal, while four resulted in perfect recovery.

The prognosis as to the development of various forms of nervous disturbance in later years as the result of cortical hemorrhage has long been considered to be very serious. While probably a great many small pial extravasations are reabsorbed and cause ultimately no nervous lesion, it is an undoubted fact that many of the epilepsies and the spastic diplegias, monoplegias, and paraplegias of childhood can be traced directly to such hemorrhages at birth. The very important point to be determined at present is as to whether the operation of removing such clots will suffice in the sequel to prevent the development of the nervous diseases mentioned. It will be interesting in the course of a few years to learn the later history of Cushing's four recovery cases, as well as of many others that must necessarily be operated upon in the near future; for that the operation is an eminently justifiable one, and that it will shortly secure the support of obstetricians generally, the writer is firmly convinced.

Treatment.—The French authors already mentioned believe that the diagnostic method of lumbar puncture has also a therapeutic value. To the writer, however, it seems that the amount of blood removed, or removable, by lumbar puncture, apart from the undoubted danger of sudden death which it entails, can never be more than a minimal proportion of the total amount effused; and that therefore, though the symptoms of compression may be obviated and life saved, the ultimate organization of clot with resulting adhesions, which is the cause, as is believed, of late paralyses, will not be prevented in this way, and that therefore the therapeutic indication has been only imperfectly met.

The possibility of treating these cases by purely medical means cannot be entertained; while the rationale of operation to remove the effused blood is very clear. It was Keen who in 1901, so far as I can find, first proposed the opening of the skull in these conditions. But he appears to have had no opportunity of carrying the plan into effect. In 1904 Harvey Cushing performed the first operation, and in 1905 he published the details of four cases thus treated, and proved that the objections of the obstetricians as to the difficulty of diagnosis and as to the uselessness, if not the certain fatality, of the operation were not entirely justified. As already said, Cushing's last report concerns nine cases, of which five died and four recovered. These were operated upon from the second to the twelfth day. In three the skull was opened on both sides, and in two a secondary operation was necessary. The indications for the operation may be deduced from the symptoms as above described. His method consisted briefly in the turning down of a flap containing the greater part of the parietal bone. This, with the thin skull of the infant, is a comparatively simple procedure. The bone can be cut with fair ease with a heavy ordinary pair of scissors, curved on the flat. The author has found by work on the cadaver that the Sudeck fraise works efficiently on these thin skulls, and very quickly. The dura is then opened, concentrically with the bone incision, and the effused blood, if free in the subdural space, is washed out with a gentle stream of salt solution. Any forcible stream must be avoided, as we know from laboratory experiments. Goltz used to excite severe irritative symptoms, especially respiratory, by projecting a stream of water upon the cortex of animals. Any clot present may be scooped out with a blunt spoon. If the blood has spread in the meshes of the arachnoid it will be rather difficult to get it out. The arachnoid should be torn open at a non-vascular spot and the clot carefully picked out. The dura is then resutured carefully, the bone flap replaced, and the wound closed without drainage. Cushing lays very great stress upon the necessity of keeping up heat by wrapping the child in cotton-wool.

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X. CEPHALOCELE.

A protrusion of the cranial contents through a gap in the cranium is given the name of cephalocele. Classification of the condition is made usually from two points of view: first as to situation, and second as to contents.

It is evident that the contents may consist of brain matter covered by all of the meninges and containing cerebro-spinal fluid. Any one of these constituents may be alone present. If the protrusion be purely of the dura mater containing only cerebro-spinal fluid, it is called a *Meningocele.* If it consist only of brain matter it is called an *Encephalocele,* while a condition in which there is present a covering of brain substance enclosing cerebro-spinal fluid and communicating directly with one of the ventricles is called an *Encephalo-cystocele,* or sometimes *Hydrencephalocele.* If the meninges cover this protrusion and there exist cerebro-spinal fluid between them and the brain surface, it is called *Encephalo-Cysto-Meningocele.*

Practically speaking, these distinctions are not of great value; the one thing necessary to know is that by far the most common condition is that in which the protrusion contains a layer of brain substance over which the dura mater is lacking, encloses cerebro-spinal fluid, and communicates, by a neck of very variable size, with the interior of one of the ventricles. The layer of brain substance may by distention be thinned out to such a degree as to be unrecognizable as such; indeed, it may disappear altogether and leave nothing but a layer of columnar ependymal cells as sole witness of its ventricular origin. von Bergmann believes that a pure meningocele is probably nothing but this last atrophic condition of an encephalo-cystocele; and that, on the other hand, the true encephalocele represents also an encephalo-cystocele undergoing retrogression in the sense that the cerebro-spinal fluid is no longer found outside the skull.

As to the coverings, the pericranium as well as the bone is usually absent; not infrequently also the dura shows a gap and is attached only at the edges of the cleft. A communication with one of the ventricles is almost constant, but in rare instances it may be reduced to a very small opening allowing the passage of not more than a probe.

In situation these tumors occupy the middle line always. The majority are found in the occipital region, some in the sincipital, and a very few at the base, protruding then into the mouth or nares.

The occipital cephaloceles are further divided into superior and inferior; the former being situated above the external occipital protuberance, that is, above the tentorium, and communicating with the posterior horn of one lateral ventricle, while the latter are below it and communicate usually with the fourth ventricle. (See Figs. 38 and 39.)

The sincipital tumors all communicate with the anterior horn of the lateral ventricle, and practically always the gap in the cranium is situated in the horizontal plate of the ethmoid. They project at the point of the glabella at the inner angle of the eye, and the lesion is well illustrated by the accompanying figures. (Figs. 40-41.)

Fig. 38.—Inferior Occipital Cephalocele. (Dr. Kenneth Cameron's case, *Montreal Med. Jour.*, 1893.) Operation was apparently successful; the child improved for several weeks, but ultimately died of an intercurrent diarrhœa.

Etiology.—The etiology, as with all purely congenital conditions, is extremely vague. Spring believed that a hydrops of the ventricle forced its way, by pressure, out through the closed skull. Meckel thought this occurred before closure of the vault, and prevented that closure. These hypotheses were discredited by Berger and by Muscatello,* probably with reason. In any case they fail to explain the original hydrops. Harvey Cushing believes, however, that the defect is probably not the primary factor leading to the hernia, but rather that some intracranial condition leading to increased tension and associated in some way with the cerebro-spinal fluid is present in fœtal life; and he points out that in adults no protrusion occurs without intracranial pressure. Berger's theory, to the effect that the protrusion represents a true congenital tumor of brain substance, an encephaloma, dislocated outside the skull, was probably based on imperfect histological observation, as Muscatello points out. According to the latter, whose investigation of the subject is admirable, the condition represents a localized arrest of development in bone growth belonging to the earliest period of fœtal life. The dura is

* Muscatello: Arch. f. klin. Chir., Bd. 47, p. 146.

similarly involved. The resulting gap in the cranial covering induces, by reason of the lessened local resistance, an increase in pressure in the cerebral and meningeal vessels of the neighboring brain area, consequently a hernia through the bony opening. Subsequently, as a result of the permanent circulatory disturbance in this area, a light chronic inflammation develops in the ependymal lining of the protrusion, and this leads to overproduction of fluid with consequent increase in the size of the cephalocele. It has been possible in a few instances to produce an analogous condition in animals by operation upon the very young fœtus.

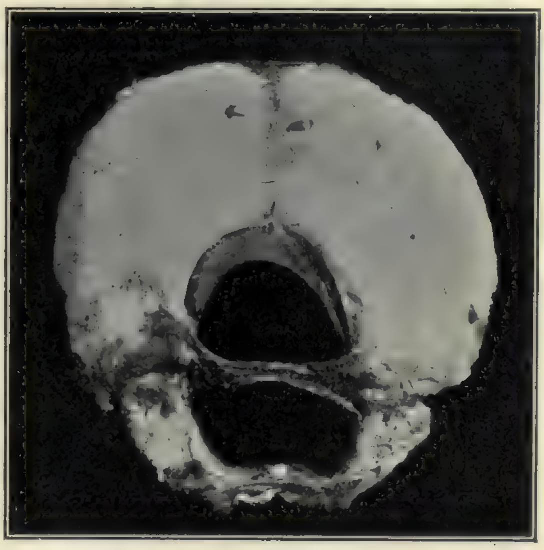


Fig. 39.—Specimen Removed from Case Shown in Fig. 38. The lower opening represents the foramen magnum, the upper is the unusually large defect which gave issue to the cephalocele.

Symptoms.—The tumor is usually clearly cystic and elastic to the feel. The sac is often translucent; pulsation is frequently made out, although also not seldom absent; and when the child cries, the tumor becomes tense. Occasionally, however, the sac is surrounded by new growth of a fatty, fibrous, or vascular character, in which case it will feel firm and possibly lobulated. von Recklinghausen explains these coincident growths as representing a dislocation of mesoblastic tissue secondary to that failure in development which leads to the cephalocele; both probably owning the one cause. The cephalocele may be pediculated or sessile, and the bony defect may be very small or very large. A good example of the latter is seen in the illustration here reproduced of Dr. K. Cameron's case. (Fig. 39.)

The contents cannot usually be reduced into the cranial cavity to any great extent. Nevertheless, some of the fluid is beyond a doubt forced into the cavity, for the signs of cerebral irritation in the way of crying, convulsive movements, and finally stupor, which the procedure caused, furnished the earliest proofs of the existence of cerebral compression as the cause of what we now call "compression symptoms." (Magendie, von Bergmann.)

Diagnosis.—The condition has to be differentiated from the acquired hernia cerebri; from spurious or traumatic meningocele; also from dermoid cysts and soft angiomata. The differentiation is easy when it is remembered that the cephalocele is always situated in the middle line and is always congenital. A skiagram, by demonstrating the gap in the skull, will in many cases render the diagnosis certain. Very rarely a basal cephalocele,* projecting in the nares or in the mouth, may simulate a polyp, and indeed in one or two instances operation under this mistaken diagnosis was the direct cause of death. The differentiation of the various forms of cephalocele is very difficult. Such considerations as those of size, form, situation, the possibility of reduction under pressure, and the size of the pedicle, are all unreliable. Even transparency does not exclude the presence of solid matter. In a general way, it may be said that the wider the gap in the bone (if it can be felt), the more likely is the presence of brain substance in the sac. The coexistence of other congenital anomalies of the skeleton speaks also in favor of a hernia of brain. Horsley

a b

FIG. 40.—Superior Sincipital Cephalocele, before (*a*) and after (*b*) Operation. (Lyssenkow, in Chipault, "État Actuel," etc., vol. ii., Fig. 23, p. 51.)

proposed faradism as a test of the inclusion of cerebral matter, and in one case was thus enabled to diagnose the presence, in the sac, of the corpora quadrigemina, as proven by post-mortem examination later.

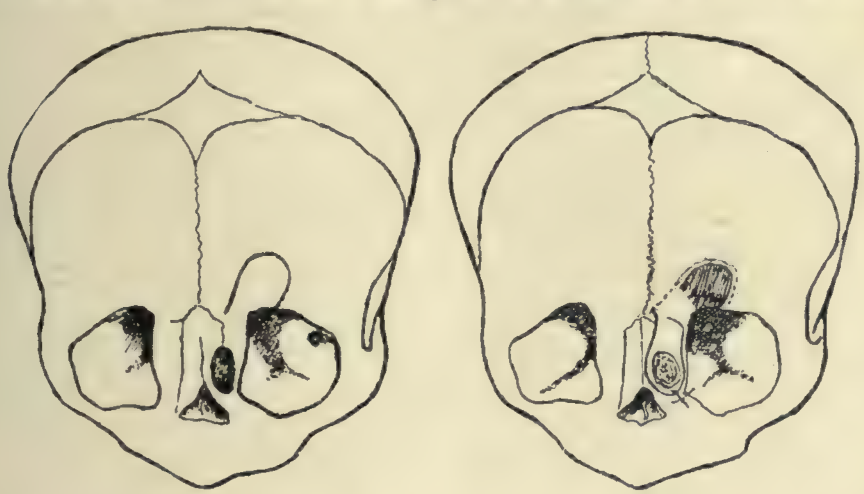
PROGNOSIS.—The prognosis is quite dark. There is frequently the concomitant condition of hydrocephalus. The babies, as a rule, die in the first few weeks or months, and perhaps most frequently as a result of pressure necrosis of the skin, with subsequent infection and meningitis.

TREATMENT.—It is hardly necessary in these days even to refer to the older methods of continuous pressure, of repeated puncture, and especially of the injection of irritating fluids; these are useless, to say the least, and may be harmful. The occasional success, reported in the earlier literature, as the result of adopting these measures, concerned, in all probability, cases in which the gap in the skull was very small, and, as has been pointed out, such conditions are much

* Exner: "Ueber Basalencephalocele," Deutsche Zeit. f. Chir.. September, 1907 (with bibliography).

more certainly cured by operation. As to operation, the indications for its employment are very few. Other serious congenital conditions must be excluded. von Bergmann would not admit to operation those cases in which there is evident hydrocephalus, those in which the cranium is clearly too small; those cases of inferior occipital cephalocele in which there is a large gap communicating not alone with the foramen magnum but also with the upper cervical vertebræ; or those in which other severe congenital deformities exist. The presence of brain matter in the sac is not a contra-indication; it is usually much thinned out and may be removed with the sac. Favorable cases are those in which the gap in the skull is small.

The operation consists in careful dissection of the sac from the skin and subcutaneous tissue down to the opening, just as in the radical cure of intestinal



a *b*

Fig. 41.—Inferior Sincipital Cephalocele. Diagrams showing method of closing the bony opening by an osteoplastic flap cut from the supraorbital ridge (Wolff-Koenig principle). In *a* is shown the gap in the bone and the line of incision; in *b* the flap reflected, with skin surface inward and osteo-periosteal surface, shaded in black, outward. (Alexandrov in Chipault, "État Actuel," etc., vol. ii., p. 57.)

hernia; in the ligature and cutting off of the sac at this level; and then in firm closure of the soft parts, using as much as may be possible the pericranium and the occipito-frontalis. This closure by soft parts will suffice for very small openings; for the larger, the application of a narrow clamp, with division of the sac and sewing with catgut, will be required. An osteoplastic method has been devised for the same purpose by Lyssenkow. This is very similar to the Koenig-Mueller osteoplasty, and is sufficiently illustrated by the accompanying figure. (Fig. 41.) The osteal flap in infants can rarely be made to include only half the cranial thickness, as the infant's skull is so thin, and it is therefore better to take the whole thickness of the cranium. The value, however, of such extensive operations on these infants is very dubious. If a closure by soft parts alone prove insufficient, it will be because of too great intracranial tension, probably from coincident hydrocephalus; and if such be present, no operation is advisable, while an autoplastic closure would probably also be insufficient, if not directly harmful.

As to results, Diakonow, in 1893, published 27 cases with 17 recoveries. Lyssenkow in 1898 had 62 cases with 33 recoveries, and von Bergmann 8 with 7 recoveries. The operation is clearly successful in properly selected cases.

XI. HYDROCEPHALUS.

The term "hydrocephalus" is applied more or less indiscriminately to any collection of cerebro-spinal fluid inside the cranium. In this sense it may be an external or an internal hydrocephalus, in the one case being situated between the brain and dura, and in the other within the ventricles. A further classification along clinical lines is into the "acute" and "chronic" forms, and a still further division, based upon its cause, or its lack of cause, is into the "acquired" and the "congenital" or "idiopathic" forms.

Hydrocephalus Externus.—This is a term used perhaps more widely in the past than at present. It designated any collection of cerebro-spinal fluid outside the cortex, from an extensive œdema of the pia up to that congenital developmental fault which consists in a lack of development of the cerebrum in the presence of a normal cranium, so that there remains a large space between the brain and cranium which is filled up *e vacuo* by cerebro-spinal fluid. The term included also such collections as were due to an original meningitis, whether infected or traumatic, with subsequent adhesions in the arachnoid or intradural space; also the cysts which form after hemorrhage into and destruction of the cerebral substance; and those collections which replace atrophied areas of brain, such as are seen in the porencephalus of children and in the cerebral atrophy of the insane. It does not matter very much whether the term be still held to include all these various forms, or not; the tendency is now to limit it to the congenital lack of cerebral development as above indicated. The other inflammatory and traumatic collections will be referred to more particularly in their proper places.

The practical interest of the external form, from the surgical point of view, is therefore slight, and we may pass on to the more important and more frequent internal hydrocephalus.

Hydrocephalus Internus.—This condition represents that disturbance in the mutual relations of secretion and absorption of cerebro-spinal fluid which results in the retention, within the ventricular space and the spinal canal, of large quantities of cerebro-spinal fluid. In location the fluid may be confined to the ventricles alone, or to the spinal canal alone, but usually it is found in both places.

Etiology.—It must be remembered that such a collection of fluid is no more in itself a disease-entity than is for instance œdema of the legs. Both are the expression of some underlying cause. In the case of hydrocephalus internus of the acquired form, the causative factor is very often quite evident, but in the congenital form it is frequently obscure. If the matter be considered from a general point of view, it is conceivable that the nature of the cause may be two-fold. In the first place, if it be taken for granted, upon the evidence of Halliburton, Findlay, and others, that the fluid is a true secretion and not an exudate or transudate, the cause may lie in a hypersecretion of the original secreting cells, probably those of the ependyma overlying the choroid plexus. Or, in the second place, the cause may be purely a mechanical one, consisting in an obstruction to the outflow of the fluid normally formed. Naturally a combination of the two causes is also possible, even likely.

With regard to the first, the evidence of hypersecretion is yet somewhat uncertain. Pathologically, the ependyma has been found sometimes thickened from a supposed inflammatory process; yet such thickening cannot be considered the direct cause of hypersecretion—it may be the result. Again, there may be stagnation in the veins leading from the choroid plexus, a stagnation due to thrombosis or to the pressure of tumors. The veins particularly concerned are the trunk and radicles of the vena Galeni, which have but a slight collateral circulation. These carry off the venous blood from the telæ choroideæ themselves and the adjacent parts of the brain. The trunk vein lies between the corpus callosum and the cerebellum, and it has been made clear from pathological findings that the block at this point will cause a stasis transudation from the choroid plexus and consequently an internal hydrocephalus. In a few cases (Spiller and Camp), the obstruction, when it has developed rapidly, has caused an exudation of blood into the ventricles. In the second place, as already said, there may be an obstruction to the outflow of fluid already formed.

In this connection the circulation of the cerebro-spinal fluid may be briefly recalled: Formed in the ventricles, it flows through the aqueduct of Sylvius into the fourth ventricle, and from here through the foramina of Magendie and of Luschka into the subarachnoid spaces, over the roof and sides of the fourth ventricle, where it has a free course down the spinal canal and over the cortex of the cerebrum. Its reabsorption into the blood from this point has been definitely shown to be chiefly into the longitudinal sinus and particularly by way of the Pacchionian granulations. Very little escapes along the sheaths of the cranial and spinal nerves. Under these circumstances it is conceivable that the obstruction to reabsorption may lie at one of several points: (1) At some point in the ventricular passages; (2) at the foramina of Magendie and Luschka; (3) at the entrance of the cerebral veins into the longitudinal sinus; (4) the obstruction may result from a generalized compression of the arachnoid space. In addition to these there may occur a block at the foramen magnum by a squeezing of the brain-stem, through intracranial pressure, into that opening like a cork, with the effect of separating the vertebral and cranial cavities. These are the possibilities, mechanically considered, of causation in internal hydrocephalus.

Now when we come to inquire what such an obstruction may consist in, we find, speaking generally, that it is only in the acquired form that we can discover the cause. The congenital condition very frequently shows at post-mortem examination no lesion sufficient to explain the abnormal retention of cerebro-spinal fluid, and, as usual, we call it, out of our ignorance, "idiopathic."

The cause of acquired internal hydrocephalus resides in obstruction, at one of the points already mentioned, of the passages through which the cerebro-spinal fluid circulates, usually by tumors or by the constricting effect of inflammatory adhesions. Hydrocephalus, therefore, as caused in this way, will be considered more particularly under these diseases. In this place we shall consider more fully only the congenital form.

Congenital Hydrocephalus.—Here, as already said, one searches in vain for the cause that one has learned to expect in the acquired form. Various suppositions have been advanced, such as that there has been during fœtal life a meningitis which in some way has started an oversecretion of cerebro-spinal fluid and has prevented its reabsorption. While the mere fact of fœtal meningitis has been proven in the case of syphilis, evidence is entirely lacking for the view that it has been present as the result of other systemic diseases, or that it has been the direct cause of a hydrocephalus. As a usual thing, no trace of it can be found post mortem. It is true that the ependyma is frequently thickened, yet such a chronic ependymitis may be as well the result as the cause. In any case it cannot with certainty be considered a source of extra secretion.

Symptoms.—Ill-understood as the etiology of the condition is, its clinical entity is by contrast extremely well established. "Water on the brain" has been known since the time of Hippocrates, who tapped the ventricles for it. The amount held in the ventricles is frequently very large, as much as two or even three litres having been found. The communication between the ventricle and the spinal canal is usually quite free; and the difficulty is to determine what prevents reabsorption of the fluid. Where is the obstruction? It does not seem to be within the ventricles, nor at the foramina of Magendie or Luschka, nor at the foramen magnum; and one is reduced to supposing with Cushing that it must lie probably at the only other possible ponit of exit, that of the longitudinal sinus. "Here," he says, "there may be some congenital anomaly which prevents the normal outflow."

The symptoms of congenital hydrocephalus are usually so clear that the ordinary layman diagnoses the condition at sight. They are chiefly due to the mechanical results of retention of water inside the brain. In the early stages the chief sign is the expansion of the skull. The baby's head, the mother thinks, is too large for its age; and, as she watches it from week to week, this fact becomes sadly more and more evident. As the weeks go on, the skull expansion becomes progressively greater, ultimately enormous; the eyes are forced downward underneath the lower lids by the projection of the orbital plates into the orbit; the ears tilt outward so that the meatus looks down; the scalp is much thinned and is traversed by dilated veins. The head lies as a heavy inert mass, so heavy that the child cannot sit up, nor move it upon the pillow. The fontanelles become enormously enlarged and the sutures widely separated (*vide* Figs. 42 and 43). The bones of the skull become thinned, and where the head rests upon the pillow there may develop a pressure sore, which in extreme instances may even penetrate to the dura. The child is feeble· it does

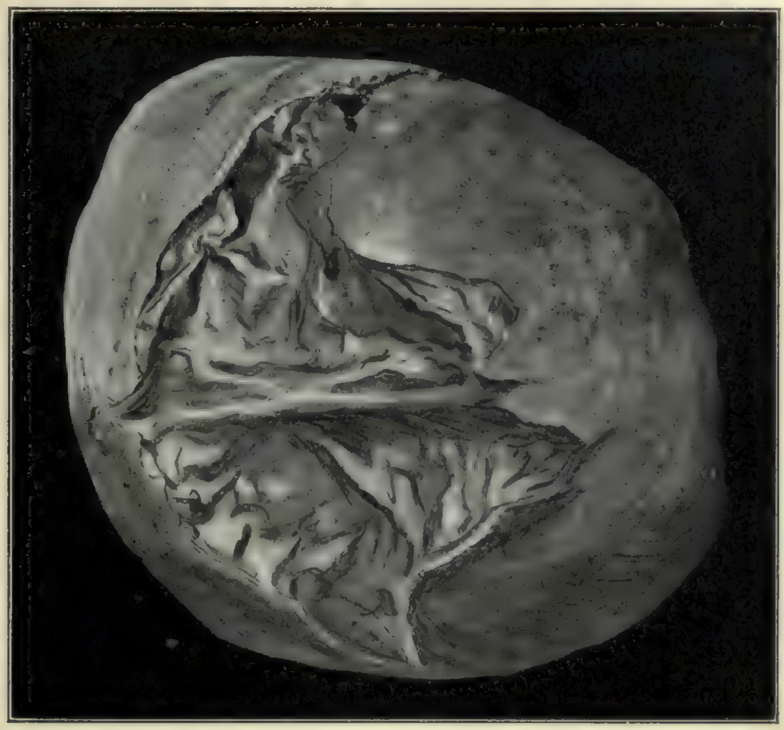


Fig. 42.—Calvarium of a Case of Advanced Hydrocephalus, Showing the Extraordinary Size of the Fontanelle. The folds in the dura represent, of course, post-mortem falling in. (From the McGill Pathological Museum, No. 91, 77, 2.)

not grow normally; its early increase in weight gradually gives way to emaciation, and very frequently it dies within the first few months. During this time its mental condition shows a corresponding lack of development; it ceases to notice things, often becomes blind, and ultimately finishes its little life as a spinal animal. In some cases irritative signs are prominent: The child cries day and night, whether from headache or not, one can hardly say; and it may be exceedingly restless. Ultimately, disturbances in the motor tract develop in the form of spasticities and contractures, rarely, if ever, of paralyses.

Such is the description of a type case; but it must be remembered that in rare instances a well-developed hydrocephalus may become stationary, and that even normal growth may succeed. Most physicians are familiar with one or two cases, in their practice, of adults possessing normal intelligence and fairly normal bodily growth, whose heads indicate that in infancy there was a marked condition of internal hydrocephalus. On the other hand, an early cessation of increase in size of the head may prove to be no more than a remission; the child lives to the age of a few years, only to die of recurrent trouble. In general, it may be said that the majority die during birth, the condition having developed

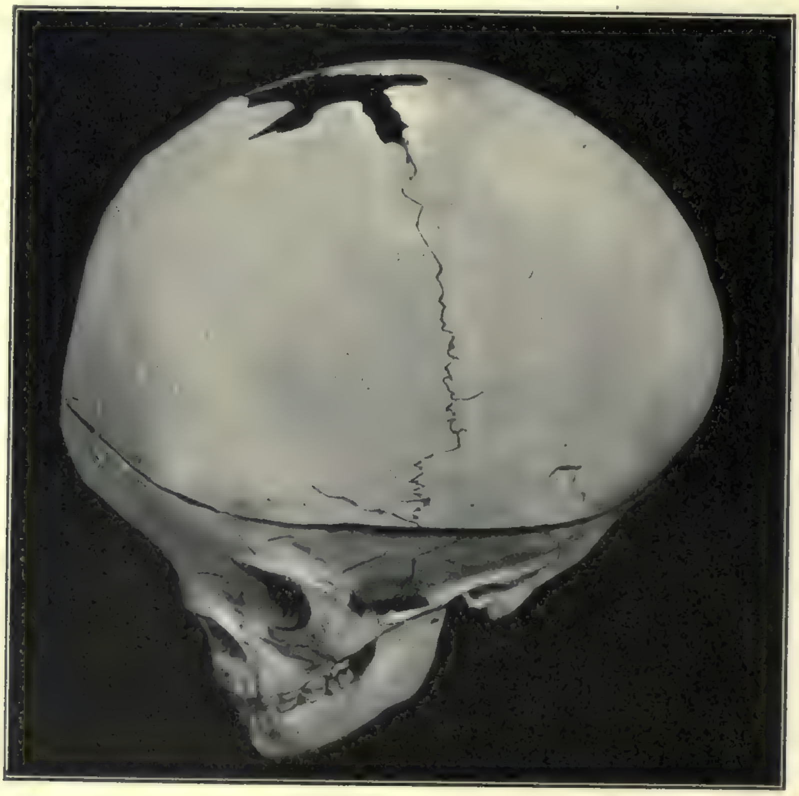


FIG. 43.—The Skull of a Case of Congenital Internal Hydrocephalus. A milder grade of distention than that of Fig. 42. (From the McGill Pathological Museum, 91, 77, 1.)

in utero. In other cases the child is born normally, but quickly develops hydrocephalus and dies within the first year. Very few pass the age of three years. The rate of the increase varies. There are cases that run their course in a few weeks, and others that run a course of many months.

DIAGNOSIS.—The diagnosis of congenital hydrocephalus in infants depends largely upon the objective signs of increase in the size of the skull. The figures showing the normal rate of growth are here quoted from Schultz, who reproduces Bonnifay's table:

Age.	Horizontal Circumference of the Head.		
	Average.	Maximum.	Minimum.
	Millimetres.	Millimetres.	Millimetres.
Birth to fifteenth day	343.9	361	318
Fifteenth day to two months	368.7	395	336
At three months	388.8	420	330
Six months to one year	429.8	465	390
One year to two years	459.7	488	340

The actual increase in the horizontal circumference, according to Bonnifay, is as follows:

Normal Rapidity of Growth of the Head.

During first three months: 44.9 mm.	From six months to one year: 29.9 mm.
From three to six months: 41.0 mm.	During the second year: 13.8 mm.

During the third year: 13.9 mm.

Mere increase in size, however, is insufficient for sure diagnosis. In infancy and childhood the most common cause of such an increase is rickets. Yet the difficulty in diagnosis concerns only the early stages, before the characteristic deformity of hydrocephalus is manifest. The chief difference between the two lies in the rate of increase, which is much greater in hydrocephalus than in the other. In rickets, moreover, the signs of cerebral compression lack entirely, while those proper to the bony changes in other parts of the skeleton are present. Yet the two diseases not seldom coincide.

The differentiation from tumor, especially a subtentorial one, in a child that has got past the first twelve months of life, may be very difficult, even impossible. The nearer birth the enlargement of the head shows itself, the more likely is it to be a congenital hydrocephalus. The nature of the pressure symptoms may give a clue; if they are unusually clear and increase in a definite order, they are much more suggestive of tumor.

Treatment.—Hippocrates tapped the ventricles, probably without any greater permanent benefit than his successors have obtained. Ventricular puncture has been carried out many times and has frequently given temporary relief, but the fluid always reaccumulates. In a very few instances repeated punctures seem to have ultimately brought the process to cessation. So few, however, are these that, in any particular instance, one is justified in supposing that the case was one of those that would have undergone spontaneous cure. Of lumbar puncture, which, following Quincke's article, had a great vogue, the same may be said. Many have tried it repeatedly, but the unanimous verdict has been that it is not of any permanent benefit.

The experiments of the earlier workers on cerebral compression (confirmed in 1896 by Leonard Hill) showed that the tension of the cerebro-spinal fluid and that of the cerebral veins were normally the same, and that if the cerebro-spinal fluid came under an excess of tension it immediately escaped directly from the subdural and subarachnoid spaces into the veins. This led naturally to the surgical conclusion that, if one could lead the cerebro-spinal fluid from the ventricles into the intradural or subarachnoid space, it ought to find a ready escape into the venous sinus, and so be carried off into the general circulation. This conclusion was drawn by Sutherland and Watson Cheyne in 1898, and they reported at that time several cases in which this apparent physiological indication had been fulfilled by placing a drain of catgut strands through the cortex so that one end lay in the ventricular, the other in the intradural space. Since that time the operation has been done probably a great number of times, and reported a few times. It may be said that the results have been very disappointing; the originators have, so far as I know, ceased to report further cases. In the Royal Victoria Hospital five such patients have been operated upon by this method,* four of whom died within a few days or a few weeks; the fifth is living and is reported improved after the lapse of one year. Naturally, one can hardly draw conclusions from such a small series. The material used for draining has varied, and catgut, silkworm gut, copper, silver, or gold tubes have been used by different surgeons at different times.

It is hardly necessary to do more than refer to the earlier attempts to drain the fluid from the ventricles directly out to the surface into sterile dressings. Such attempts usually resulted either in immediate high fever and death, within a day or two, from too rapid evacuation of the fluid (a common occurrence), or else in infection. Other operators have tried to drain from the ventricles to the subcutaneous tissues. The latest proposal, and in some respects the most rational one, is that of Harvey Cushing, who says that he has utilized it in 12 cases "with a considerable measure of success." His contention is that, inasmuch as in the great majority of cases no obstruction can be found within the ventricles, nor at the foramina in the roof and sides of the fourth ventricle, nor between the cranial and vertebral cavities, therefore the obstruction to the outflow must lie, as above indicated, at the entrance into the longitudinal sinus; consequently the drainage of ventricular fluid into the intradural space is wrong in principle. The fluid must be carried off to some part of the body altogether outside the cranio-vertebral space—a part from which it may be absorbed. His somewhat formidable procedure is as follows.

First of all, it is necessary to establish the fact of free communication between the ventricles and the spinal subarachnoid spaces. This he does by simultaneous measurement of the pressure in each cavity. This being determined, a laparotomy is performed and the body of the first or second lumbar vertebra is

* In the services of Dr. Bell and Dr. Garrow.

bored through with a small trephine; and into this hole is pushed one-half of a silver tube which has been made to fit exactly the size of the trephine opening. Then a laminectomy is done, the spinal cord pushed aside, and the other half of the silver tube, made with a catch so as to lock into the first half, is pushed into the trephine opening from the lumbar side. The wounds are then completely closed. This represents, put briefly, the drainage of the cranio-vertebral cavity as a whole into the retroperitoneal tissue. One can hardly find any fault with the rationale of the procedure if those cases in which an obstruction at the foramen magnum is the cause of the hydrocephalus can be ruled out. The only criticism to offer would concern the severity of the procedure; a combined laparotomy and laminectomy is rather formidable. We shall await with much interest the publication of the cases in detail.

Sutherland and Cheyne, in Lancet, 1898.
A. S. Taylor: The Treatment of Chronic Internal Hydrocephalus by Auto-drainage. American Journal of Medical Sciences, 1904, vol. cxxviii., p. 255 (with bibliography).
T. Schulze, in Nothnagel's System, 1901, Bd. ix., iii., 1.
H. Cushing, in Keen's System of Surgery, vol. iii., 1908.

Acquired Hydrocephalus.—In this form we are able usually to discover a certain or a very probable cause for the obstructive retention of fluid. An obstruction is usually situated in the roof of the fourth ventricle at the foramina of Magendie and Luschka; it generally results from the adhesion of the pia-arachnoid to the brain-stem, and cuts off the subarachnoid spaces as a whole from the ventricles. The obstruction may also be caused by mere mechanical pressure as from a tumor. It is probable that a vicious circle is easily established. A primary obstruction in the region of the fourth ventricle, which may be of a temporary nature, may induce an acute hydrocephalus, which, diminishing the general intracranial space, presses the brain-stem down into the foramen magnum in such a way as to cut off the cranial from the vertebral cavities. Escape by way of the spinal canal no longer being possible, the ventricular distention becomes the more marked; and so on in a circle, with the result that there occurs a sort of self-strangulation on the part of the brain, a condition which, even though the primary cause be removed, as for instance by the absorption of a meningeal exudate, is apt to perpetuate itself. The condition may thus be frequently acute, going on in a few days to death by compression under the exact picture which one sees in the laboratory experiment, as has been described in a previous section. In other cases the process may be subacute or even chronic, lasting months; and it may show fluctuations. While the acquired form may occur in early infancy, particularly as the result of the posterior basic meningitis described by Barlow and later by Still, and can then be differentiated from the congenital form only by a definite history pointing to meningitis, as a rule it first develops somewhat later, in fact at any period of life after the fontanelles have closed; and this simply because the ordinary causes of the acquired form, chiefly meningitis and tumor, do not occur with any frequency in infancy. Under these circumstances, the very large head, characteristic of the congenital form, is usually absent; the cranial bones having united into a solid whole, the acuteness of the process usually leads to death within a short time. The symptoms, therefore, are chiefly those of cerebral compression superimposed upon a substructure which is referable to the particular causal disease. The patient goes through a stage of irritation characterized by restlessness, headache, delirium, hallucinations, twitchings of the limbs and of the eyes, and arrives at what may be called the paralytic stage, in which occurs stupor or complete unconsciousness together with spastic motor signs. Characteristic of these is the rigid extension of the legs with contracted toes, and flexion of the upper extremities with clenched fingers. Retraction of the neck is nearly constant. Percussion of the head may reveal, over the distended ventricular cavities, a peculiar note reminiscent of the cracked-pot sound. Macewen first described this, and Koplik has lately laid great emphasis upon it, not only as a diagnostic sign but as an indication for lumbar puncture. The further details concerning the prognosis and treatment of the condition may be reserved for the sections concerned with the underlying causal diseases.

XII. INFLAMMATION OF THE LEPTOMENINGES.

Inflammation affecting the pia-arachnoid may be primary or secondary, local or general. The type of the primary form is seen in cerebro-spinal fever, or, as Kaupe prefers to call it, epidemic meningitis. To this group also apparently belong some cases of the so-called serous meningitis and the posterior basic meningitis of Barlow, although probably at least some of the latter are in reality instances of cerebro-spinal meningitis. When secondary, the disease owes its origin to a variety of lesions, the greater number of which are either traumatic or otogenic in origin. Tuberculous meningitis is usually secondary to a focus elsewhere, although sometimes it seems to be primary in the sense in which we speak of a primary affection of the kidney, the original disease being glandular and of small extent. In the course of the infectious fevers also there may arise a meningitis which in some seems to be purely serous and due to the circulating toxins of the disease, while in others it becomes frankly infective in character and results in a purulent meningitis.

Pathologically, one finds a local increase of serous fluid in the arachnoid spaces, and, if the process spread to the choroid plexuses and the ependyma, an increase in the ventricular fluid. Speaking in a general way, this primary condition may lead on to a definite hydrocephalus, probably by preventing proper reabsorption of cerebro-spinal fluid, partly also by inducing an increase in its production. This condition becomes very definite if, as a result of meningeal thickening around the fourth ventricle, the ventricular cavities are converted into a closed sac. With the general increase in fluid, the cerebro-spinal tension is generally raised throughout the two cavities, and, if lumbar puncture be performed at this stage, the pressure registered may be very high, in some cases as high as 700 mm. of water. The relief of tension afforded by lumbar puncture, sometimes repeated, may in rare instances be sufficient to restore proper intracranial circulation and relieve compression; then, with subsidence of the inflammation, recovery may ensue. If, however, tension is maintained or increased, there becomes evident, in many cases, a tendency for the communication between the cranial and spinal cavities to become blocked by a descent of the brain-stem into the foramen magnum. The existing hydrocephalus is immediately increased, the value of lumbar puncture naturally ceases to exist, and there arises a clear indication for ventricular puncture or drainage. These remarks apply in a very general way to the pathology and to the clinical course of meningitis as taken in the gross.

Tuberculous Meningitis.—In a work of this character it is hardy necessary to do more than refer briefly to the details of the pathology and symptomatology of the various meningitides, except in so far as they possess a surgical bearing. For the former the reader is referred to the books on internal medicine. The process in the tuberculous inflammation is nearly always confined to the base, particularly the interpeduncular space and down over the pons and medulla; but sometimes it spreads up around the sides and involves the cortical meninges as high as the Sylvian fissure. Very rarely indeed does it go higher. In nature, the exudate varies from a thin, somewhat turbid, serous fluid to one of a thick fibrinous infiltration. In any case it is rarely of considerable amount. The superficial cellular layers of the cortex may be affected to a slight degree by the inflammatory process. The exudate may be sufficient to cause, by direct pressure, paralysis of the cranial nerves, chiefly the third, sixth, fifth, seventh, and eighth; but the main result of the meningeal inflammation is to cause, in addition to the reactionary outpouring of serous or fibrinous fluid, a definite increase in the amount of cerebro-spinal fluid, so that upon lumbar puncture an intrathecal pressure of as much as 700 mm. of water may be registered. The fibrinous exudate first mentioned is quite incapable, by reason of its small quantity, of causing any material degree of cerebral compression, though doubtless it is sufficient to produce the severe headache of the earlier stages, but the extraordinary augmentation of the cerebro-spinal fluid may in a sense be closely compared with the experimental introduction of salt solution into the subarachnoid spaces, such as we are familiar with in laboratory work, and it may also reproduce with great fidelity the experimental picture of general cerebral compression. For a certain time this high pressure observed in lumbar puncture, which indicates distention generalized throughout both cranial cavities and the spinal canal, is maintained; but, in cases in which one repeats the procedure frequently, there often comes a time when the high pressure of yesterday is found to have disappeared, and the fluid drops from the needle at what seems even subnormal tension. Such an event can hardly be interpreted save as the evidence of an acute block at the foramen magnum. Probably the intracranial pressure has driven the brain-stem into the foramen magnum like a cork. In the writer's experience, the communication may sometimes be re-established on the succeeding day, and lumbar pressure then again becomes high; but if it is not re-established, the cranial accumulation is apt to increase rapidly and to hasten the fatal issue by cerebral compression. In just what proportion of cases this occurs is uncertain; but pathological evidence goes to show that an acute hydrops is frequent, and is in all probability the immediate cause of death in many of the cases. In saying this the writer does not lose sight of the fact that the picture is often complicated by the presence of serious coincident lesions. It is well known that, in over half the cases, tuberculous meningitis is only one expression of a generalized miliary tuberculosis, the toxæmic effect of which is often clearly traceable in the clinical picture. Or, again, there is not infrequently an advanced tuberculosis in the lungs or elsewhere, of which the meningitis is no more than a terminal complication.* Apart from all these considerations, however, there remains a fair proportion of cases in which the signs of generalized cerebral compression so dominate the clinical picture that they may be said to be the chief factor in the causation of death.

Symptoms.—It is hardly necessary to describe these in detail. The insidious onset, with steady progression of symptoms, is characteristic. The serous and fibrinous exudate by its pressure, together with the toxæmia of the disease, causes agonizing headache, gradually increasing restlessness, culminating in delirium with hallucinations; the systemic signs of fever are present; and there develop twitchings of the limbs, nystagmus, and local cranial-nerve palsies. Ultimately the restlessness gives way first to stupor and then to coma as the hydrocephalus and consequent compression increase; and, as already said, death often ensues apparently as the direct result of the compression. The pulse-rate, it is true, is frequently kept comparatively high by the coincidence of fever; yet often, too, it is relatively slow, not, for instance, materially over 100. If the child, before death, lies in a semiconscious state, with rigid muscles, periodic respiration, and such mechanical symptoms of increased pressure as a tense fontanelle (when the patient is young enough) and optic neuritis, it is difficult to resist the conclusion that the predominating factor in the disease is a hydrocephalus. So true is this that many internists are accustomed to divide the course of the disease into three stages: that of irritation, that of compression, and that of paralysis.

* In an analysis by Professor Adami and Dr. McCrae of 1,000 autopsies at the Royal Victoria Hospital, there were 30 cases of tuberculous meningitis, of which 21 showed the presence of widespread tuberculosis elsewhere.

Prognosis.—The disease is uniformly fatal. Very rare indeed are the instances in which spontaneous recovery is said to have occurred, and in most of these the diagnosis cannot have been certain. With lumbar puncture, however, and the demonstration of the bacilli in the puncture fluid, there have been recorded two or three cases of recovery.

Treatment.—The question is whether we cannot do something to relieve the condition of cerebral compression consequent upon the hydrocephalus, in the hope that, by staving off death from this cause, the original process may be given time to undergo that spontaneous cure which is so frequently seen when the disease attacks other parts of the body. Notwithstanding the frequent coincidence of widespread tubercles elsewhere and the ill-success of surgical intervention hitherto, may we still not hope that in selected cases it may be possible to do good by relieving intracranial pressure? It was in this idea that von Bergmann in 1888 performed ventricular puncture and established drainage from the ventricle to the exterior in three cases; that Parkin and later Waterhouse in 1893 trephined the occipital fossa after Morton's method and placed a drain under the inferior medullary velum; that, in 1892, Essex Wynter, Mr. Hulke and Mr. Gould in the Middlesex Hospital drained the lumbar spaces, even doing a laminectomy to insure the placing of the drain; that Quincke and many others after him did lumbar puncture repeatedly; that Stephen Paget did laminectomy and incised the dura in the cervical region; and that Chipault advised the drainage of the subarachnoid space in the Sylvian fissure. Others, especially Ballance, have called attention to the good effect of laparotomy in tuberculous peritonitis, and have suggested that the exposure and superficial drainage of the meningeal spaces by trephining might accomplish analogous results. It is conceivable that the analogy is justified as to the good effect of mere exposure; but drainage, as well as irrigation, is in general quite impossible; the exudate is usually slight and is imprisoned in the arachnoid meshes, and the brain bulges into the trephine opening. The results have been all lamentably discouraging. Two patients seem to have been saved. Ord and Waterhouse (*Lancet*, 1894, Vol. I., p. 597) drained the inferor medullary velum and the patient recovered. Here, however, the bacilli were not demonstrated, though clinically the diagnosis seemed certain. One patient of Barth's (*Münch. med. Woch.*, 1902, No. XXI., p. 877) and one of Riebold's (quoted by Kaupe, *Centralblatt f. d. Grenzgeb. d. Med. und Chir.*, 1906, Vol. IX., Nos. 21, 22, 23) survived, the bacilli having been demonstrated in the lumbar-puncture fluid. In Riebold's case daily punctures had been made to the number of twenty-four. Short of cure, there has been observed occasionally temporary improvement in the compression symptoms. The value of lumbar puncture is therefore definitely proven to be minimal.

The writer cannot refrain from entering on a short consideration of forms of treatment which many might consider as quite outside the pale of controversy, being convinced that the question of surgical interference in tuberculous meningitis is not yet settled in the negative; and for these reasons.

In certain cases it is found clinically that there is a lack of fatal tuberculous lesions in other parts of the body; in the course of the disease a diagnosis of hydrocephalic compression as the chief factor in the causation of the approaching fatal issue can be made while the patient is still fairly strong and well nourished; the tendency of tuberculosis elsewhere is often toward spontaneous cure; the obstruction at the foramina in the fourth ventricle is of a temporary nature; there exists consequently the possibility of permanent relief from the hydrocephalus if the temporary obstruction can be tided over; the meningitis is absolutely fatal if left to run its course. Add to these the objections that may reasonably be urged against previous surgical procedures: for instance, that lumbar puncture becomes useless at that stage in the case when the spinal canal becomes blocked off from the cranial cavity, at the foramen magnum; that ventricular puncture, unless repeated very frequently (as appears not to have been done), can have only a temporary effect; that drainage into aseptic dressings almost inevitably leads to infection, if it does not kill the patient by a too rapid evacuation of the cerebro-spinal fluid, with hyperthermia. On the other hand, drainage in the inferior cerebellar space, in some respects the most rational procedure, although possibly too severe in feeble patients, has been attempted but a very few times, yet, in these, it can record one success.

In view of all these considerations, it seems to the writer that it would still be justifiable to attempt as a routine measure, in such cases as have been indicated above, some measure of decompression, either by removal of bone or by short-circuiting the ventricular fluid into the subarachnoid or intradural spaces, so that it may take its normal exit by way of the cerebral veins and sinuses. This last is primarily what is aimed at by the drainage of the inferior medullary velum, but I think it would be preferable to employ in these cases the procedure advised by Sutherland and Cheyne, and by Taylor, for congenital hydrocephalus, because of the inflamed condition of the subtentorial meninges and the presumable interference with reabsorption; and because also of the lack in this situation of Pacchionian bodies. Some little time ago I believed that the intermusculo-temporal decompression operation of Cushing might fulfil the indications best, and I performed it on one patient, a man of twenty-five, with definite temporary relief to compression symptoms; but, unfortunately, I did not combine with it, or perhaps substitute for it, as I would do now, ventriculo-intradural drainage. As I was preparing, however, to supplement it by this procedure, the patient reached the breaking-point, and passed so rapidly into the paralytic stage that to do anything further was considered useless. His blood pressure was recorded every two to four hours, and showed first the immediate drop of nearly 50 mm. Hg (from 155) upon decompression, and then its gradual rise during the following five days before death. At post-mortem examination the pressure of the brain-stem against the rim of the foramen magnum was seen in a distinct furrow, which was much less marked on the side of the decompression than on the other, intact side. One other similar case has been recorded by Eyster.* In this case Cushing did the decompression operation as a symptomatic measure; death occurred on the sixth day after temporary relief.

To me the point of view is this: In a disease which is absolutely fatal, it is justifiable to adopt any surgical measure which, being based upon sound clinical, pathological, and physiological reasoning, would *a priori* seem to offer even a remote chance of saving life. In the disease which we are now considering, to propose surgical intervention is the more justifiable in that the operation involves neither mutilation nor additional pain; on the contrary, it is likely to relieve pain as the effect of decompression; and, finally, it adds nothing of mental distress to the patient, who is usually in such a condition as not to know what is being done. Nor can it be said that the procedure would be likely to hasten death; but even if it did, that could hardly be counted an objection in the face of such a fatal disease.

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Cerebro-spinal Meningitis.—This infectious fever, the morbid expression of which is curiously confined almost altogether to an inflammation of the cranial and spinal meninges, occurs both in the sporadic and in the epidemic form, and may affect any age. It is probable that the posterior basic meningitis of infants described by Gee and Barlow, the bacteriology of which was later investigated by Still, is in many instances identical with cerebro-spinal meningitis.

Pathology.—The pathological lesions vary from an acute intense hyperæmia of the meninges—characterized by a comparatively small amount of serous exudate in which it may be very difficult to find the organism, and leading to

* *Loc. cit.*, p. 124.

death within twenty-four hours or even less—to a chronic hydrocephalus, with clear sterile fluid which is the sole remaining expression of an acute and widespread inflammation. In the ordinary cases the exudate is abundant. At first sero-purulent, it soon becomes frankly purulent, and often quite thick and fibrinous, thus showing a marked difference from that of tuberculous meningitis. In extent, also, it differs from the latter in that, while usually involving the base, it spreads with great regularity up over the cortex also. The leptomeninges of the two regions, as the exudate becomes fibrinous, may be converted into a regular sheath of the central nervous system. As distinguished from the tuberculous form the onset of the disease is sharp and sudden and its tendency toward spontaneous recovery much greater, the fatality in various epidemics ranging from twenty to eighty per cent.

Symptomatology.—It is unnecessary to go into the details of the symptomatology. Let it suffice to say that, together with the general symptoms of an acute febrile disease, the picture is dominated by the signs of meningeal irritation—photophobia, pains in the head, back, and limbs, restlessness, irritability, muscular twitchings and tremors, retraction of the head, Kernig's sign. What concerns the medical attendant chiefly during the acute stage is the complication of obstructive hydrocephalus, which threatens life by way of cerebral compression. The manner in which this occurs has been sufficiently indicated in the section on Tuberculous Meningitis. Here, as there, there can be no doubt but that in a certain proportion of cases it is the direct cause of death. Lumbar puncture, which shows, for a certain time during the disease, heightened pressure, and evacuates a considerable amount of fluid, becomes at a given moment inefficient, and clearly does nothing more than empty what fluid has collected in the spinal theca. Following this a ventricular hydrops may develop.

This condition of internal hydrocephalus may develop at one of two stages in the disease: either during the acute stage, or somewhat later, after an interval of convalescence. In the former instance the signs of cerebral compression may be, if one is not on the lookout for them, somewhat masked by the constitutional effects of the disease; yet usually the development of a relatively slow pulse, with rise in blood pressure and increase of stupor, is sufficient to betray the condition. Koplik emphasizes the value, at this stage, of systematic percussion of the skull according to Macewen's method. The hydrocephalic condition is early expressed in a change of the percussion note, which is usually described as suggestive of the cracked-pot sound; it gives "an idea of hollowness." With the patient sitting, the most resonant note is got toward the basal level of the frontal bone and over the squamous portion of the parietal. If the head be inclined to one side the note on the inferior surface becomes more tympanitic than at the upper side. Koplik believes that it is sufficiently definite to aid in the differentiation of the so-called meningism, which represents toxic irritation of the meninges in the course of pneumonia or of cerebro-spinal fever, from true meningitis with hydrocephalus. In a few cases, as Koplik further points out, acute hydrocephalus may come on within the first thirty hours, and is then characterized by sudden signs of pressure with the paralytic signs of rapid weak pulse, sighing respiration, and the evidences of collapse. In one such case timely recognition of the cause of these symptoms led to an immediate lumbar puncture, with the withdrawal of 50 c.c. of fluid and the apparent saving of life.

In a second class the hydrocephalus comes on gradually during convalescence. The child seems to be doing well, yet, almost unnoticed at first, there develops gradually a progressive lack of interest in things. Generally the child lies quite still and no longer plays with its toys; it seems to get the habit of picking its nose, biting the nails, or scratching the body; it grows pale and silent, anwers in monosyllables; the eyes become somewhat staring; cerebral vomiting appears, yet this is not apt to be severe, nor does it interfere with the taking of food, in fact the child continues to take large quantities of nourishment, and the mother is surprised, in view of this fact, to observe a progressive emaciation which ultimately becomes extreme. After a certain lapse of time the child sinks into stupor; reacts to no ordinary external impulse, save to cry when interfered with; the head is markedly retracted; the legs are held in extreme extension and the arms in flexion. The disease may thus continue to progress for a period of over four months before death affords relief.

Another condition which may suggest or admit surgical intervention concerns the effect, in cured cases, of the cortical adhesions which represent the organization of the exudate. These may induce epilepsy and sometimes also mental deficiency.

Prognosis.—The outlook varies widely with the epidemic; in other words, with the virulence of the organism. This renders difficult, to a certain extent, any accurate estimate of the value of lumbar puncture and other surgical procedures. Some epidemics have shown a mortality as low as twenty per cent others as high as eighty per cent. Still, in comparison with other forms of purulent meningitis, the average prognosis as to life is decidedly favorable.

Treatment.—The value of surgical measures has to be estimated from two points of view. In the first place, it can hardly be doubted but that the removal by lumbar puncture, for instance, of large quantities of infected cerebrospinal fluid must act to a slight extent like the drainage of any infected cavity. Yet the limits here, after all, are narrowly set. As the disease progresses, the exudate tends more and more to become thick and fibrinous and to be held in the meshes of the arachnoid, so that ultimately the large amounts obtained in early punctures diminish to the point of a few drops. This of course, as already said, may indicate not a subsidence of the total amount, but the occurrence of a block at the foramen magnum. The second thing aimed at is, as has been already sufficiently indicated, the relief of the tension which results from the development of an internal hydrocephalus; and this, so far as surgery is concerned, represents certainly the chief vital indication. The measures which have been already mentioned in speaking of tuberculous meningitis have all been applied to the treatment of this form also.

Lumbar puncture has been freely recommended by a number of authors, and seems to have been definitely curative in many cases. Zupnik (*Prager med. Woch.*, 1906, Nos. 37 and 38) claimed that it should be done continuously every day, or every second day, and that the spinal sac should be emptied each time. He often in one sitting drew off from 70 to 90 c.c. without damage. Of 10 cases he treated 4 after this fashion; all of these patients recovered, while the other 6 died. Bokay and Baginsky also strongly favor this plan of treatment. The latter advised, however, not to remove more than 30 c.c. at once. Of 17 cases he obtained recovery in 10. In these the total amount of fluid removed varied from 165 to 350 c.c. And so with a number of other observers. Nevertheless, it seems certain that in the majority of cases lumbar puncture, while of temporary benefit, ultimately fails to save life; this is in the main the experience at the Royal Victoria Hospital. In such the cause of death is often hydrocephalus.

Investigations by Goeppert are worth noting. By cadaver injections with colored gelatin in fatal cases of cerebro-spinal fever he found that of 26 cases there was complete closure of all exits from the skull in 4; that in 7 there was closure of the foramen of Magendie, but compensatory widening of the foramen of Luschka; that in 15 there was no organic obstruction between the ventricular and the spinal cavity. It is, however, probable, as Schultz points out, that there may exist during life an obstruction at the foramen magnum (caused probably by the pressure of the dilated posterior horns upon the cerebellum), which is relieved after death. This is indicated by certain instances of simultaneous lumbar and ventricular puncture in which the pressure in the ventricles was high, that in the spinal canal low, and yet after death no obstruction could be found.

In all these cases, lumbar puncture, once a block has occurred, can serve only to increase hydrocephalus by removing the supporting column of spinal fluid, and allowing a more solid corking up of the foramen magnum by the brain-stem and cerebellum. Under these circumstances, the indication seems clear for ventricular puncture, and this operation, in fact, has frequently been done, yet apparently without, so far, any degree of success.

Schultz concludes that repeated punctures—for usually they have to be repeated to meet the reaccumulation of fluid—are nevertheless justifiable, because the underlying causes of the hydrocephalus do show a tendency to spontaneous cure in not a few cases, and therefore, if we can tide over the immediate danger, nature will be given an opportunity to set things right ultimately. The symptomatic relief is nearly always marked, and that alone is sufficient to make the slight procedure worth while. Instead of repeated punctures, it has been suggested to put in a permanent drain from ventricle to intradural space. Radmann has designed a small wire frame, holding four drainage wicks, which he has used in two cases operated upon in the later stages. Great improvement resulted, but the patients ultimately died. In a few cases lumbar laminectomy has been done in order to irrigate and drain the spinal canal, and the first operation of this kind was suggested and carried out by Harvey Cushing in 1898, though unsuccessfully. The procedure was successful in a case of Rolleston and Allingham, yet can hardly be considered justifiable. Ballance has suggested the drainage of the cistern around the brain-stem by the suboccipital route, and this is approved by Cushing. This is still, however, in the theoretical stage. All these failures of surgical procedures which are based upon rational physiological grounds are certainly disheartening, yet it must be remembered that up to the present the total number of such interferences is small; that they have been reserved for the late stages of hydrocephalus; that, further, operating upon patients who show signs of generalized compression is not to be advocated, and this is especially true in the case of patients who are enfeebled by a long illness. It may therefore be reasonably held that a larger operative series may show a certain, though small, number of cures, particularly when the complication of hydrocephalus can be recognized in its earlier stages, and with an earlier resort to surgical intervention. Certain it is that when hydrocephalus has developed, spontaneous relief is hardly to be hoped for; and that, the longer one waits and the greater the degree of compression, the more dangerous does surgical procedure become.

The late very encouraging results* from the use of Flexner's serum do not alter the surgical indications as here laid down, inasmuch as the latter depend chiefly upon the mechanically produced condition of hydrocephalus, a condition which is naturally uninfluenced by the use of serum; in fact, as Flexner points out, the serum is of value chiefly in the first few days of the disease, while hydrocephalus is most often a complication of later development. Although the writer has as yet had no opportunity of operating upon these cases, it is his conviction that decompression, together with the routine drainage of the ventricles either into the intradural space or into the subcutaneous tissues, is decidedly indicated in these cases. One remarkable observation in this regard was published by Boswell. A child of five developed, during convalescence, epileptiform seizures, with progressive emaciation and persistent fever. Boswell trephined on the fifty-eighth day of the disease the right parietal region, and incised the dura. In the next few days a considerable amount of fluid escaped. The drain was taken out in a week, the wound healed rapidly, and there followed an uninterrupted recovery, the symptoms having subsided immediately after the operation. This can hardly be interpreted otherwise than as a mechanical relief of the tension of hydrocephalus.

Late Complications.—Though the disease may apparently progress to recovery, there may remain a chronic hydrocephalus of moderate degree which shows itself in a persistence of epileptiform convulsions, a semi-stuporous con-

* Of 47 cases treated with the serum, 34 recovered and 13 died.

dition, cranial-nerve palsies, especially strabismus, and a persistence of emaciation. Also adhesions may form over the cortex as the expression of an organization of the exudate, and these may doubtless play a part in the exciting of epilepsy. Cushing records a case in which both conditions were present, and he was able to effect a cure by separating adhesions on both sides and by simultaneous lumbar and ventricular punctures. It is possible, however, that in these cases the epilepsy is due rather to the hydrocephalus than to the adhesions; and one gets the idea, in analyzing the various cases reported, that, where cure results from punctures or trephining, the actual relief of tension at the moment is comparatively slight. If one conceive of the hydrocephalus as the result of a vicious circle in which the ventricular space has, as it were, strangled itself at the neck,—that is, at the foramen of Magendie,—it is evident that it might need but a comparatively small evacuation of fluid to relieve the pressure at the foramen, and so give a start to the process of reabsorption which then might take its natural course, just as occurs in the case of pleurisy with effusion, where the removal of a small amount of fluid is followed by the spontaneous reabsorption of the rest.

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Serous Meningitis.—As Eichhorst showed in 1887, there is a form of meningitis, acute in its onset, the exudation of which may remain serous throughout its course. The pathological nature of this disease, so far as it has been examined, is simple enough. There are hyperæmia of the meninges and an excess of fluid; that may be all. Its pathological entity seems to depend rather on a negation; in other words, the definite causative agents, which we are accustomed to find in other meningeal infections, are here wanting, and we call it "serous" and "amicrobic," in contradistinction to "suppurative" or "tuberculous," etc. We are reduced to assuming that it depends on the chemical action of the toxins of bacteria which are located elsewhere, usually in some focus of frank infection. The meningeal outpouring is simply irritative. Such a definition applies to the narrower conception of the disease as set up, for instance, by Quincke. Thus a serous meningitis may be a localized process at first, or may indeed remain so throughout, as in the instances of middle-ear and mastoid infection, which provoke, through the intact dura, an irritative serous exudation in the middle fossa, just as there may develop, through the intact diaphragm, a sterile serous pleural effusion from a subphrenic abscess or from a carious rib. A similar condition of a more unimpeachably aseptic character is seen as the result of trauma of the skull and the meninges. A serous meningitis may be general from the start, and is then frequently due to some infection at a distance acting through the blood and probably by its toxins and germs. This form of meningitis occurs in the course of infectious fevers, especially pneumonia and typhoid. Or, again, it may depend upon disturbances which are not microbic, such as alcoholism and the terminal stages of uræmia. In some instances the pathogenesis remains absolutely obscure; none of these causes is found, and the symptoms are altogether those of cerebral compression from hydrocephalus, superimposed upon those of meningeal irritation. Here the fluid remains serous and sterile throughout, as has been proved by repeated lumbar punctures; and the relief afforded by these punctures is ultimately curative. This is *meningitis serosa* in the narrower sense; and, as has been often remarked, it is diagnosed not from its symptoms, but from its curability. It must be remembered, however, that in many of the instances of serous meningitis dependent upon infection of neighboring structures, especially the cranial bones, or upon infection at a distance, the fluid in the course of time may become purulent.

Perhaps the most typical cases of serous meningitis are those with which the otologists have made us familiar as resulting from mastoid infections. This side of the subject will be discussed in another part of this work. Here there need only be mentioned its great frequency, its easy curability by removal of the infected bone, or, if necessary, by lumbar or ventricular puncture. An analogous condition is seen in the neighborhood of a subdural or cortical abscess and is then characterized by intermittent attacks simulating meningitis. Here the serous exudation is simply a marked expression of collateral œdema.

Symptomatology.—The symptoms, as already said, are those of meningeal irritation on the one hand, and of cerebral compression on the other. There is hardly need to go over these again in detail. The latter may be localized or general: in the one, dependent on compression of a localized collection of fluid or on a focus of encephalitis; in the other, on the development of a hydrocephalus. Ordinarily the diagnosis is not made before operation, or, in unoperated cases, before cure, which is then brought about usually by lumbar puncture. The operation, however, which is usually undertaken under the diagnosis of suppurative meningitis following ear disease, or of cerebral abscess, reveals no more than a collection of serous fluid; or frequently the exploratory punctures, made in the idea of discovering an abscess, penetrate the ventricle, and it is the ventricular puncture that relieves tension and brings about a quite unexpected recovery. This indeed is the treatment; and in no other form of meningitis is it so successful. The condition may become chronic if not relieved in one of these ways. It is then constituted by an internal hydrocephalus. In such instances the symptoms simulate tumor, and the diagnosis, as Saenger has emphasized, may be very difficult to make.

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Posterior Basal Meningitis of Infants.—Investigations of Gee and Barlow established some twenty years ago a clinical disease entity characterized chiefly by the occurrence of severe meningeal symptoms confined to the posterior part of the base, and occurring chiefly or only in infants; and, later, Still discovered in a large number of these cases a special diplococcus. Lately we have come to think that probably many of these are in reality instances of cerebro-spinal fever in infants; on the one hand, because Still's organism resembles very closely that of Weichselbaum, and, on the other, because Koplik has found in the middle of an epidemic of cerebro-spinal fever a number of cases clinically typical of Barlow's form, in some of which the specific diplococcus of the cerebro-spinal disease was found. There are the usual symptoms of meningitis, but they are clearly limited to the posterior fossa. There exist all grades of severity; but not infrequently the illness terminates in recovery. Hildesheim has called attention to the especial frequency of the complication of hydrocephalus in this form of meningitis, and also to the fact that such a hydrocephalus is frequently confounded with the congenital form. This would be a very natural mistake if the meningeal history were not marked. The writer has seen lately an instance in point. The child was thirteen months old, and the mother said that the head had begun to enlarge at the age of three months. It was only upon investigating the history more closely that one obtained from the mother a history of symptoms indicating clearly an attack of posterior basal meningitis at the age of two months, which had presumably blocked the foramen magnum by inflammatory adhesions.

In thirty-eight out of fifty autopsies Lees and Barlow found hydrocephalus, and remarked that it is the hydrocephalus rather than the meningitis that proves fatal, and Hildesheim says that hydrocephalus is so frequent a result that it might almost be considered a symptom. (See Fig. 44.) Even where the disease seems to have been overcome for the time being, there occasionally develop sequelæ which may be referred in all probability to the development of a "concealed hydrocephalus" without head enlargement—sequelæ which are expressed in so-called recurrences of the meningitis, in attacks of vomiting and stupor, in paralyses, mental deficiency, and even sometimes in sudden death.

TREATMENT.—The Parkin operation of opening into the inferior medullary velum by going in through the occipital bone has been tried by Ballance in a number of cases, but all of the infants died save one. He found the operation too severe. Abandoning this operation, he has employed the method of ventric-

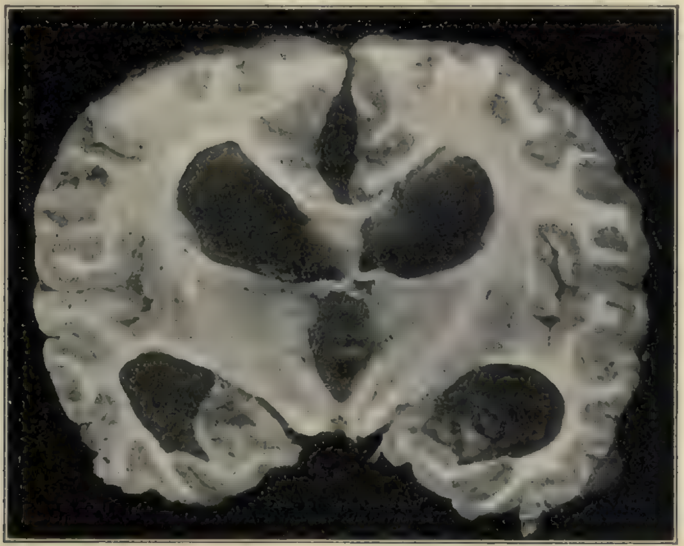

FIG. 44.—Chronic Hydrocephalus. Coronal section of brain. Note the great dilatation of both lateral ventricles and the third ventricle, as well as of the descending horns. The patient, a child, had gradually developed paralysis of all its limbs, save the left hand; death from marasmus. The underlying disease was a chronic posterior basal meningitis, with, probably, mechanical retention by inflammatory closure of the foramen of Magendie. (Path. Dept., Royal Victoria Hospital, 52, 1906. Kindness of Dr. Robins.)

ulo-intradural drainage, a small gold tube being used for the purpose, and reports one successful case. Theoretically the latter mode of treatment should prove more successful in this condition than in congenital hydrocephalus, inasmuch as there is ordinarily a definite obstruction at the fourth ventricle which may, after subsidence of the inflammation, disappear. Certainly it is clearly justifiable to perform such an operation, save where the infant is *in extremis*.

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Suppurative Meningitis.—The organisms concerned in this form of meningeal inflammation are the various kinds of staphylococci, chiefly the aureus, and the streptococci. Less often one finds such bacteria as the pneumococcus, the pyogenes fœtidus, the colon bacillus, the typhoid bacillus, and others less well known. The starting point of the disease is usually a fracture of the skull, communicating either with the nose or pharynx or with the ear; it is also frequently an infection in the accessory sinuses of the nose and ear.

Traumatic suppurative meningitis is due to infection introduced through a bursting fracture, with its fissure opening to the surface, or to a punctured fracture; or again it may result from infection of a wound in the scalp or the cranial bones. In these instances the path of infection is by contiguous extension, or by a phlebitis of the emissary veins.

Noetzel has lately investigated experimentally the liability of the leptomeninges to infection, and has found that, while less susceptible than joint surfaces, they are much more so than the serous surfaces of other cavities such as the peritoneum or pleura. The writer well remembers the oft-repeated teaching of the late von Mikulicz concerning the need of asepsis in various operations, to the effect that the entering of the cranial cavity was, as he expressed it, a "hyper-aseptic" operation. Undoubtedly, the degree of aseptic precautions which the surgeon is accustomed to use with success, or, perhaps, with impunity, in operations upon the peritoneum, may be found to be insufficient when it comes to opening the meningeal spaces.

Symptoms.—Ordinarily the symptoms of meningeal infection, when it complicates the course of a cranial trauma, arise within a few days of the accident. If the patient has recovered from the concussion effects and his sensorium is clear, he will show signs of infection, such as headache, and sometimes pain in the body; he becomes restless, his temperature rises, the pulse becomes more rapid, and respiration also. In the course of a day or two, if the process be acute, these signs of meningeal irritation and of systemic infection increase rapidly. Extreme restlessness and delirium may appear; palsies of the cranial nerves, chiefly of those supplying the ocular and facial muscles, develop; pain becomes agonizing; the deep reflexes are increased. If a wound be present, it will often assume the appearance of being infected. If the process spread, as it not infrequently does, to the bulbar and spinal meninges, there will occur stiffness and retraction of the neck, and sometimes of the back muscles; Kernig's sign is often present. Although the exudate sometimes becomes quite large, it is rare in this form of meningitis for the bulbar signs of general compression to appear. Whether compression is induced or not, it would seem as if the high fever, rapid pulse and respiration of the systemic poisoning prevent the usual effects of generalized compression on the medullary centres. Toward the end, the patient sinks into unconsciousness, and he dies in coma with a small rapid pulse that persists as usual after cessation of respiration.

Such are the symptoms of a diffuse suppurative meningitis; but if, as sometimes happens, the infection remains local, there develops a meningeal abscess; and around this, there frequently arises a collateral œdema. If the abscess be situated over an area giving focal signs, one gets the particular signs of pressure in that region, combined with those of general infection.

Treatment.—In the past, to trephine for cases of local meningitis has been counted more or less useless, although many instances of success are recorded; but to trephine where the process is generalized has been regarded as mere "Operationslust," as the Germans term it. There can be no doubt, as is shown by the good results obtained by the otologists, that the evacuation of local collections of pus in the intradural space is not only justifiable, but is commendable. The trouble is that in the traumatic cases, or in those following osteomyelitic infections of the cranial bone, the process rarely is localized. The conditions usually favor an early generalization by means of the cerebrospinal fluid. Once the process is generalized, and particularly if lumbar puncture demonstrates that the spinal meninges are also affected, it must be admitted that the condition is wellnigh hopeless. Nevertheless, there are a few cases on record in which craniotomy has apparently sufficed to bring about cure. One of these, that reported by Kuemmell, is so striking that it may well be reproduced in this place.

A man suffering from a basal fracture, with considerable loss of cerebro-spinal fluid from the nose in the first day or two, developed, on the sixth day, symptoms of meningitis, which, during the succeeding three days, became apparently generalized throughout the cranial and spinal cavities, as was proved by lumbar puncture. By the ninth day after the accident, the patient seemed moribund; he was in deep coma; breathing was stertorous; there was intense rigidity of the neck; temperature was high; the pulse slow, yet small and thready; there was general flaccidity of the muscles; otherwise there were no focal signs. Kuemmell trephined on both sides low down in the occipital region, taking out bone over an area as large as a five-mark piece (circa 1½ in. in diameter), and incising the dura which was under great tension. Only a small amount of purulent fluid was evacuated. A gauze drain was pushed down deep in the occipital fossa. Next day, there was marked improvement, though the patient was still comatose; but, subsequently, convalescence was rapid. On the second day lumbar puncture showed that the fluid was still purulent, but on the sixth day it was clear.

It is evident that in this instance the operation was life-saving. Whether the result was due to decompression or to the means of escape afforded to pus is doubtful. Of the latter but very little was evacuated. The case, as a whole, is extremely important in that it shows the possibility of cure by operative means in a meningitis which was apparently generalized. Once such a possibility of cure is established, the right to intervene early must be allowed; and then we shall have a right to expect that, in this otherwise hopeless condition, a certain limited number of cases may be saved.

This instance is not isolated. Poirier, Mignon, and Ballance have each recorded more or less similar instances. Theoretically, operation for meningeal infections has been frequently urged in the idea, on the one hand, of establishing drainage, and on the other of possibly irrigating the meningeal spaces. Such indications, however, are hardly possible of fulfilment. The amount of drainage accomplished, for instance, where with the always-present increase in intracranial tension the brain is forced up into the trephine opening, can hardly be great. Moreover, adhesions form in the neighborhood. Irrigation also, as suggested by Hill and later by Ballance, is quite impossible. The pus is largely contained in the arachnoid meshwork, the irregularities of the cranial fossæ are great; the possibility of establishing counter-openings is minimal; and, finally, the risk of increasing cerebral compression is undeniable. If trephining is to do good, it must be in the sense of decompression, chiefly; and one is inclined to the opinion of von Bergmann that repeated ventricular puncture might accomplish all that can be otherwise accomplished. In the writer's opinion, such a procedure, or possibly, the decompressive intermuscular operation of Cushing in the temporal region, is decidedly indicated in all cases, provided the patient or friends thoroughly understand the chance that such a procedure affords. Further experience upon rational lines should be had before adverse judgment is passed.

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XIII. MENINGEAL AND CEREBRAL SYPHILIS.

The frequency with which syphilis affects the tissues inside the cranium is somewhat remarkable. According to the records of the Royal Victoria Hospital, there were admitted to the medical wards, through the fourteen years of the hospital's existence, one hundred and twenty-three instances of luetic affections of various location; and of these no less than forty-two were set down as cerebral.

Pathology.—Inside the cranium, as elsewhere, the lesions caused by the action of the Spirochæta pallida show a more or less characteristic similarity in that, in spite of a great multiformity, they can all be reduced to variations in the one process. The exudation of small round cells, together with the proliferation of the fixed tissue cells, may be either diffuse and spreading, or localized within narrow limits so as to form a more or less roundish mass. In the former case there results an infiltration of the meninges which produces what may be called a plaque; or, when the process attacks a vessel, one part of the circumference of the wall, particularly the media, is infiltrated diffusely with small round cells; or the same process may occur in the perineurium of the cranial nerves. In the latter instance there is formed a gumma, either with or without the coincidence of the diffuse infiltrating lesions just described. These various lesions inside the cranium show one peculiarity as to situation, in that they practically always begin in the leptomeninges, rarely in the dura mater, and still more rarely in the cerebral substance itself. Naturally these tissues are invaded secondarily, and when the latter is involved it is not a mere pressure atrophy of the nervous substance that ensues, but an actual destruction and replacement. The lesion may therefore assume various forms. It may be the localized tumor, the gumma, which, though usually beginning in the pia-arachnoid, always penetrates the cerebral substance secondarily; there may be a syphilitic arteritis; or a perineuritis; or there may be a syphilitic meningitis. Mechanically speaking, the gumma is equivalent to a tumor of any other nature. The process of arteritis not infrequently results in the closure of the vessel lumen, most frequently by a final thrombosis; while the purely meningitic process results in the formation of a plaque-like thickening which frequently glues together dura, pia-arachnoid, and cortex, and which may be small or large, single or multiple. The importance of these lesions in the meninges and their vessels, and in the cranial nerves, is far beyond that of the mere extent of the process, inasmuch as the thrombosis resulting from arteritis, or the pressure on nerves from perineuritis, may bring about functional disturbances of capital importance; while the irritation of a small meningeal plaque may go on to a permanent epilepsy.

In situation, extent, and combination, these forms of the luetic process vary greatly, yet certain general principles may be deduced. There are those which are largely confined to the base. Here we get chiefly the diffuse infiltrations which affect the arterial walls, the sheaths of the cranial nerves, and the meninges, with the formation of patchy thickening. And there are those which affect chiefly the convexity; here we find the gumma, yet also to no small degree the plaque-like condition. The gumma seems to affect the frontal and Rolandic regions more particularly. Its size is usually not above that of a walnut. It is more often multiple than solitary, yet these multiple nodules are frequently crowded together so as to form in reality one large mass. Their line of demarcation from the brain tissue is frequently sharp. Under treatment, they usually degenerate rapidly, going through a stage of caseation, and ending in a fibrous scar of variable size. If the gumma is small, reabsorption may be apparently complete. As compared with tuberculomata, gummata rarely break down and form an abscess. In other respects the gummata possess many points of similarity with the tuberculous tumors, and the differentiation may be exceedingly difficult. Perhaps the most constant point of difference is to be found in the tendency of the gumma to end in a plaque-like scar, a result which rarely occurs in tuberculosis. The meningeal thickenings or cerebral scars which represent the end result of these more florid lesions may persist indefinitely and ultimately be the cause of epilepsy.

Symptoms.—The wide variation in situation and extent of the disease, the fact that the lesions are more frequently multiple than solitary, the differences in the predominance of the various lesions, and finally the characteristic variations in the course of the disease from causes which represent probably circulatory modifications—all these render the picture of cerebral syphilis kaleidoscopic. There may be in all cases the general signs of intracranial tension—headache, vomiting, somnolence, and choked disc. These will be most marked in the instances of large gummata which act as do other kinds of tumor, and which may kill the patient under the typical picture of cerebral compression. At the other extreme there are those conditions which are characterized by headache alone. They may be due either to a slight meningitis during the secondary stage, the only evidence of which is seen in a lymphocytosis in the lumbar-puncture fluid; or they may represent equally well a more pronounced lesion, chiefly at the base, consisting in arteritis and meningeal thickening. In a third class of cases, also chiefly basal, one finds, in addition to these general signs, definite paralyses of the cranial nerves—most often the third and sixth, occasionally the fifth, seventh, and eighth—all due to luetic perineuritis and pressure of the exudate.

In a fourth class one sees develop chiefly the symptoms of arterial disease, resulting ultimately in thrombosis, inasmuch as the favorite site of the luetic arterial infiltration is in the large arteries at the base. Thus may be produced the very serious condition of hemiplegia, due to thrombosis of the middle cerebral or one of its branches. Gowers has shown that such a condition may result from the scar contraction which treatment with potassium iodide is believed to bring about.

The manifestations hitherto mentioned concern chiefly the basal situation of the disease. When there is present a lesion on the convexity, it is most often a gumma; and this gumma is very apt to be situated either in the frontal or in the motor region. Thus we get still another class of cases in which the symptoms are chiefly cortical, and which resemble those of a tumor of any other kind in a similar situation.

Optic neuritis is not frequent in intracranial gumma. Headache, so characteristic of cerebral syphilis in all its forms, is a very prominent symptom. It is apt to be intense, with nocturnal exacerbations, and is refractory to the ordinary headache remedies.

Diagnosis.—Naturally the one sure point in the diagnosis of lues is a positive history, and this is especially true of intracranial lesions. It is evident that where such a history cannot be obtained, the diagnosis may be extremely difficult. Many are the instances in which inquiries are met with an absolute denial; and there are not a few in which confirmatory signs are lacking. In such instances we have to depend chiefly upon the characteristically remittent or intermittent course of the disease, the therapeutic test, and perhaps, most of all, upon the examination of the cerebro-spinal fluid as obtained by lumbar puncture. As observations upon the latter accumulate, the conclusion seems more and more justified that a marked lymphocytosis, other things being equal, points very strongly to the presence of syphilis of the nervous system. Indeed, the same is true of the parasyphilitic conditions. These, however, can be easily excluded in any given case.

Prognosis.—The outlook in cerebral syphilis can hardly be said to be as bright as in the case of other localizations of the disease. It has been long known that patients believed to be affected with intracranial syphilis often show a remarkable and unexplainable refractoriness to treatment. This seems to be particularly the case where the lesion present is the hard fibrous gumma. The fact has been emphasized by such authorities as Horsley, Kocher, Gowers, von Bruns, and Neumann.

It is true that in many instances the disease does yield readily to treatment, and it is probable that such cases represent particularly the flat infiltrating form, affecting chiefly the cranial nerves and the arterial walls. And it is certain that reabsorption may be so complete as to leave no macroscopical trace of the original lesion, and that clinical symptoms may disappear absolutely. Nevertheless, the percentage of cases which, after apparent cures, recur, or which from the beginning show themselves resistant to treatment, is variously estimated at from one-third to one-half of the total number.

Treatment.—It is self-evident that the best treatment of cerebral lues is the prophylactic one. A thorough course in the early stages of the disease may be expected to prevent cerebral complications. Given, however, a patient in whom cerebral symptoms are already developed, what is to be done? Treatment must of course always be at first by drugs. The only exception will concern instances where life is immediately threatened, and where there is an indication that the *causa morbi* is accessible to surgical interference. Under ordinary circumstances, with the use of mercury and potassium iodide according to well-known methods, symptoms will abate and possibly disappear. Let us suppose, however, that they do not abate. How long is drug treatment to be kept up? This is a point which has been much discussed ever since in 1890 Horsley proposed a limit of six weeks. M. Allen Starr preferred to wait three months. von Bergmann's opinion, supported by Oppenheim, was that even three months was often too short a time and that the opportunity for surgical interference was restricted to exceedingly narrow limits in cerebral syphilis. It is of course evident that figures such as six weeks or three months are not intended to be taken literally. Indeed, in Horsley's original proposal to make a time limit of six weeks, he indicated that he did so in order to provoke discussion, while maintaining merely the general correctness of the figure. The question must be decided by the condition of the patient at the time. Hitherto the tendency has been, among those who are counted the most radical, to advise operation in the presence of certain indications. These are well stated by Schlesinger:—There is, first of all, a presumable diagnosis of lues. The disease must show progression, or at least a persistence of symptoms, after the patient has been subjected to a thorough course of treatment with antiluetic remedies. The lesion should be accessible to the knife. If at any time, under these circumstances, there should develop danger to life (the *indicatio vitalis*) this constitutes a positive indication for operative interference. Finally, if epilepsy persist, even though other signs of tumor have disappeared, surgical interference is justified. On the other hand, if the patient is markedly cachectic and if he shows evidences of amyloid disease, it is unwise to operate.

During the last few years we have learned to enlarge slightly the indications enumerated above, in that it may be considered justifiable to do a decompressive operation even during the course of the antiluetic régime, if the progression of optic neuritis threatens the loss of eyesight, or if the patient is becoming exhausted by uncontrollable headache. Cushing has in several cases met these indications successfully by an intermusculo-temporal decompressive operation. It has been doubted whether operation during the terminal stages of compression is justified. That it is justified, however, can hardly be doubted in view of the occasional saving of life by free opening of the skull. Witness the patient of Horsley who was in a semiconscious condition with slow pulse and Cheyne-Stokes breathing, whose life was saved by a suboccipital trephining and the removal of a cerebellar gumma. One point in the administration of mercury deserves attention. While, for a quick introduction of the drug into the system, inunctions are probably the most efficient methods in the ordinary run of cases, yet where a particularly rapid effect must be got, it is probable that intramuscular injections will be preferable. (Voss.)

Results of Operative Treatment.—Twenty-three years ago Macewen did the first operation recorded for cerebral syphilis; and this first operation, brilliant alike (at that time) in its conception and in its result, may still be cited as full and complete justification for the surgical treatment of cerebral syphilis. Stransky, from that time down to two years ago, was able to collect 18 reported cases of operation. Of these, 15 were gummata and 3 represented meningeal plaques. Of the 15 gummata, there resulted, in 9, positive cure or great improvement. In all these an accurate local diagnosis was possible and the serious symptoms had not lasted more than a few months. In the remaining 6 the result was unsatisfactory; of these there was a failure of localization in 2: one was undertaken as a last resort during status epilepticus; and another was complicated by encephalitis. It is seen, therefore, that the outlook is poor where diagnosis is impossible or incorrect, and where the disease is too extensive, or the condition of cerebral compression too advanced. In other words, the prognosis does not depend upon the nature of the disease *per se*, but rather upon conditions which are equally applicable to all forms of tumor. It may certainly be said that the results, both as to immediate and as to ultimate cure, are superior to those obtained in the operative treatment of most other forms of tumor. The interventions in the three cases of pachymeningitis gave two partial successes and one death. In these it was found that the lesion was in each case wider than had been expected from the nature of the symptoms. In this sense the gummata offer a better outlook.

We have not as yet sufficient evidence to determine whether the removal of gummata and of meningeal plaques, in cases where it is found necessary to do this by surgical means, will prevent the later development of epilepsy; nor whether removal of late scars which, while the original lesion has been cured, are still causing cortical irritation and epilepsy, will necessarily cure the epilepsy.

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XIV. THROMBOSIS OF THE DURAL SINUSES.

Aseptic Thrombosis.—The clotting of blood in a sinus, as in any vein of the body, may be said to have a twofold causation: on the one hand, septic or infectious; on the other, aseptic, as in the traumatic and marantic varieties. At least we believe that the latter are aseptic in origin, though what the underlying cause of the clotting in such instances is we do not know. It is a process that is primary in the vein, and has probably to do with altered chemical composition of the blood itself, together with possible slowing of the rate of flow. It may be compared with the same process in the pelvic and femoral veins after aseptic operations or aseptic child-birth. We cannot be sure that organisms do not play a part in the matter; but, if so, they escape detection. However this may be, the thrombosis of marasmus occurs in the end stages of any exhausting disease, such as typhoid fever, tuberculosis, prolonged diarrhœa, cancer, etc., and it is especially liable to affect the very young and the very old. As to the longitudinal sinus, it has been thought that the fact of the blood entering at an angle and against the blood current favors the development of the clot.

SYMPTOMS.—The symptoms of this form of thrombosis are usually indefinite, being masked by those of the disease which it complicates. With the appearance of headache, drowsiness, delirium, or convulsions, the latter especially in children, one must bear in mind the possibility of cerebral sinus thrombosis; and, as a matter of clinical experience, it is in these cases that the longitudinal sinus is ordinarily affected. If in addition to these signs one finds evidence of the fact that the intracranial blood is not escaping from the skull by the ordinary path, but is taking, at least in part, a roundabout way through the veins of the cranial coverings; in other words, if one finds cyanosis and œdema of the scalp, the diagnosis becomes fairly certain.

The outlook depends naturally most upon the situation of the thrombosis and its extent, and upon the general condition in which the primary disease has left the patient. If the clot extends from the superior longitudinal sinus into the cerebral veins over an area of appreciable width, softening of the brain substance is inevitable; or, if it extend so as to involve both lateral sinuses, death from venous stasis is practically certain. A block of the longitudinal sinus alone may very well be recovered from, as collateral circulation is quite possible. Moreover, a clot here may ultimately become canalized and the lumen partially restored.

Septic Thrombosis.—It is hardly necessary to remind the reader that any inflammatory process in the wall of a vein will almost inevitably determine deposition of the white cells upon the endothelium at the point inflamed; and that from this wall thrombus there will develop a complete thrombus, which may become itself infected; or that then, under particular circumstances relating to the virulence of the bacteria involved, such a clot may break down into infected products, and, according to its access to the general blood current, may either send out metastases throughout the body with resulting pyæmia, or may form only a localized collection, which, breaking through the vessel wall, may appear on the surface.

With regard to the condition as seen in the cerebral sinuses, one finds that the primary focus of infection is nearly always situated in that part of the cranial tissues which is nearest to the sinus affected, a fact which indicates the importance etiologically of the spread of infection by contiguity. This extension may occur either by direct wandering of the bacteria through the tissues and into the sinus wall, or by a short transport through lymphatics.

Such primary head infections are found to consist in infected wounds of all sorts, erysipelas, abscesses, furuncles or carbuncles, cranial osteomyelitis, alveolar abscess, tonsillitis, and the whole list of other possible infections that may occur in this region. From our medical-student days, for instance, we have had impressed on us the danger of a carbuncle of the lip because of the possible spread of its infection along the facial veins, through those of the orbit, and so into the cavernous sinus. In the great majority of the cases, however, it is one particular infection that dominates the field of causation, and that comes from the inflammations of the middle ear and the mastoid. The frequency of otitis media as compared with other infections of the head, and the nearness of this focus to the lateral, sigmoid, and the superior petrosal sinuses, are sufficient to explain this fact. (See Plates XXXI, Fig. 2; XXXII, Fig. 1; and XXXIV.) Thus it happens that, in hospital practice at least, most cases of sinus thrombosis are seen first of all in the otological department, and that the surgeon is usually called in only when the disease has declared itself unmistakably.

Septic Thrombosis of the Sigmoid Sinus.—As this part of our subject is treated in detail in a subsequent article in this volume, we may be permitted to pass at once to a brief consideration of thrombosis as it occurs in the cavernous and superior longitudinal sinuses. In either case there may appear the general symptoms of septic invasion usually accounted characteristic of infective sigmoid-sinus thrombosis.

Thrombosis of the Superior Longitudinal Sinus.—This sinus is rarely infected, save by the inflammation of septic wounds, especially the compound depressed fractures of the vertex. Other sources of infection are seen in erysipelas and cellulitis of the scalp, and in the various forms of osteomyelitis of the cranium, whether primary or secondary. It is probable that the condition goes frequently unrecognized, partly because of the slightness of the symptoms or their masking by coincident lesions, partly because recovery is more frequent than from the septic thrombosis of other sinuses.

The symptoms are poorly marked, and are often set down to the credit of the coincident and causative lesion. Cyanosis and œdema of the scalp, epistaxis from stasis in the ethmoidal district, drowsiness with perhaps delirium, from the cerebral congestion, and the signs of severe general septic infection should make one suspect the existence of this condition. Yet all these may be equally the signs of erysipelas, cellulitis, or osteomyelitis without thrombosis of the sinus. They are more significant if they are superadded in the course of a depressed fracture. Treatment can hardly come into question, save in the course of, and as part of, an operation for the removal of bone in cases of depressed fracture or of osteomyelitis. The sinus, if evidently infected, may then be treated upon the principles which obtain in sigmoid-sinus thrombosis, by opening and evacuation of the clot.

Cavernous-Sinus Thrombosis.—Thrombosis here is usually due to the extension of an infective phlebitis from the facial or frontal through the orbital veins, or from bone infection in the sphenoid body. Less often the source of the trouble is found in some part of the naso-pharynx or in the maxillæ, either in the soft parts or in the bony structure.

The characteristic signs of this condition are: marked exophthalmos, with œdema and hemorrhages into the retina and ultimate loss of sight, œdema of the eyelids, the forehead, and the anterior part of the scalp; and then those signs which are referable to pressure on the nerve trunks which pass forward along the outer wall of the sinus—the third, fourth, and sixth,—so that ptosis, dilated pupil, and indeed often a double ophthalmoplegia, together with, in some cases, irritation of the first division of the fifth leading to hyperæsthesia in the orbital region, result. (See Plate XXXIV.) The cavernous sinus is, after all, not made up of two sinuses, for the two component parts are connected so closely with each other by the circular sinus of Ridley that they form virtually one. This explains why there is a marked tendency for the thrombosis to become bilateral.

The prognosis is extremely bad; death nearly always ensues within from a few days to a month.

Treatment by operation is practically out of the question, in view of the difficulty and danger of access and the extremely small hope of accomplishing good. Rhinologists have in rare instances attempted it without success, the route chosen by them leading through the infected sphenoidal cells.

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XV. DISEASES AND INJURIES OF THE BRAIN SUBSTANCE.

Encephalitis.—Encephalitis in its medical aspect is analogous to the anterior poliomyelitis of children, and, like it, is seen especially in children. Struempell * indeed calls it polioencephalitis. It is doubtless, with hemorrhage, the most frequent cause of infantile hemiplegia. It has a febrile onset and course and may arise apparently spontaneously; in other cases it seems to complicate the infectious diseases, and in still others it is clearly an extension from neighboring infection, especially of the cranial bones (middle-ear and mastoid). Finally, it may develop as a complication of injury. The pathological result, as in all inflammation, is an acute exudative swelling, and this may attain such a degree as to cause symptoms of generalized cerebral compression, just as the œdema of aseptic origin, as in concussion (Cannon), or that developing around a tumor, may do (*vide* Figs. 74 and 75). It may by compression be the immediate cause of death in traumatic or infective cases, though rarely so, if ever,

* Struempell, in Deutsches Arch. f. klin. Med., xlvii. Heft 1 and 2. See also Oppenheim und Cassirer: "Die Encephalitis." 2te Ausgabe, Wien. 1907

in the primary encephalitis of children. If death threatens as a result of such general compression, the signs of which are the usual ones, the symptomatic treatment—viz., the decompressive operation—would seem indicated. This is a clear indication certainly in the traumatic or infective cases, though it is hardly to be considered in the others.

The acute inflammation having subsided, the affected nerve tissue may suffer a necrosis and gradual breaking down into a cyst; and such late encephalic cysts may cause epilepsy, as in the remarkable case of Krause, where removal of the cyst brought about cure of the epilepsy.*

Naturally, the place of surgery in the condition of acute encephalitis, as ordinarily understood by the neurologist, must remain small. Yet it would seem that where infection starts in a focus of contused cerebral substance, leading in this way to a spreading traumatic encephalitis with subsequent more or less extensive softening of the brain, trephining might do good by giving room to the swollen, œdematous, and often necrotic tissue, if the latter lead to symptoms of local or general compression. Such a case has been recorded by Friedrich.† He admits that such cases, uncomplicated by a meningitis, will always be rare events; but he believes strongly in their existence, though he confesses that the diagnosis is extremely difficult.

The symptoms are said to simulate closely those of extradural hemorrhage. Coming on during the second and third days these symptoms resemble perhaps more closely those of localized intradural clot.

Cerebral Abscess.—Etiology.—The ports of entry for the infection which results in cerebral abscess may be very various. In the first place, in the great majority of cases, there is a spread by contiguity from a focus of infection in the neighborhood. This focus is usually inflamed bone, and most often the temporal bone. It may occur also by a spreading infective sinus phlebitis, or, again, it may result from infected wounds of the scalp. In the second place, the infection may be conveyed along thrombosed veins, or perhaps the lymphatics, from a distance. In the third place, it may be directly implanted by the entrance of a foreign body, as is seen so freuently in punctured fractures; and, finally, it may be brought by way of the blood from some focus in a distant part of the body.

Thus the causes of cerebral abscess may be classed as those from trauma, those by extension from neighboring infections, and those by extension from distant infections (metastatic, pyæmic). The abscess is very rarely primary, although a few such cases are recorded. This is the so-called idiopathic abscess, where careful post-mortem examination fails to reveal any primary focus of infection.

Trauma is responsible in about half the cases. Practically always it is a compound fracture, whether through the fissure of a bursting fracture which com-

* F. Kause: "Hirnchirurgie." Deutsche Klinik, 1904.

† Friedrich: Deut. Zeit. f. Chir., 1906, p. 516.

municates with ear, nose or throat, or the external skin, or through the pathway furnished by a punctured fracture. In such cases the abscess lies usually close to the site of the trauma. Occasionally it may arise in the total absence of fracture, and is then doubtless of hæmatogenous origin; witness the patient of Elder in whom an extradural clot was infected with the typhoid bacillus in a case of ambulatory typhoid. In the case of extension from neighboring bone infection it is probable that about half of all cases arise in inflammation of the middle ear or mastoid cells, much more rarely from frontal or sphenoidal sinusitis.

When the abscess is of metastatic origin the original infection may be represented by an ulcerative endocarditis, an osteomyelitis of the long bones, or, perhaps most frequently of all, by a pulmonary infection, particularly septic bronchiectasis; very rarely is it represented by typhoid, influenza, actinomycosis, glanders, or one of the other less frequent infections. In a general way the location of the infection, when cranial in origin, gives the location of the cerebral abscess: frontal or sphenoidal sinusitis is followed by an abscess in the

FIG. 45.—Dumbbell Abscess of the Right Frontal, Prefrontal, and Temporo-sphenoidal Lobes, consecutive to Chronic Suppurative Otitis Media. (Roncali's case. Chipault: "État Actuel," etc., vol. iii., p. 319.)

frontal lobe; middle-ear or mastoid disease by a temporo-sphenoidal abscess; and infection of the posterior mastoid cells by a cerebellar abscess. Although recent analyses have shown that cerebellar abscess is much more frequent than used to be supposed, the cerebrum is still affected about twice as often as the cerebellum. In 1,400 autopsies at the Royal Victoria Hospital (figures which I owe to the kindness of Dr. Adami) there were found 11 instances of cerebral abscess. Of these, 6 were in the temporo-sphenoidal lobe, 1 in the frontal, and 4 in the cerebellum. As to cause, 6 were due to middle-ear disease, 2 to tuberculosis, and 1 was metastatic in the course of a septicæmia, while 2 "idiopathic" cases remained undetermined. The ages varied from

5 to 60 years, the average being 23. When the lesion arises after an ear infection, the latter is in the vast majority of cases chronic, the usual history is that a patient with cerebral abscess has had intermittent discharge from the ear for many years.

Pathology.—The abscess may be single or multiple. If there are several, they are usually small. The single abscess may occasionally be very large, as in Roncali's patient. (Fig. 45.) Metastatic abscesses are apt to be multiple, while those from near-by infections are usually single. Encapsulation, where the abscess lasts for a considerable time, is quite frequent. In old cases the cap-

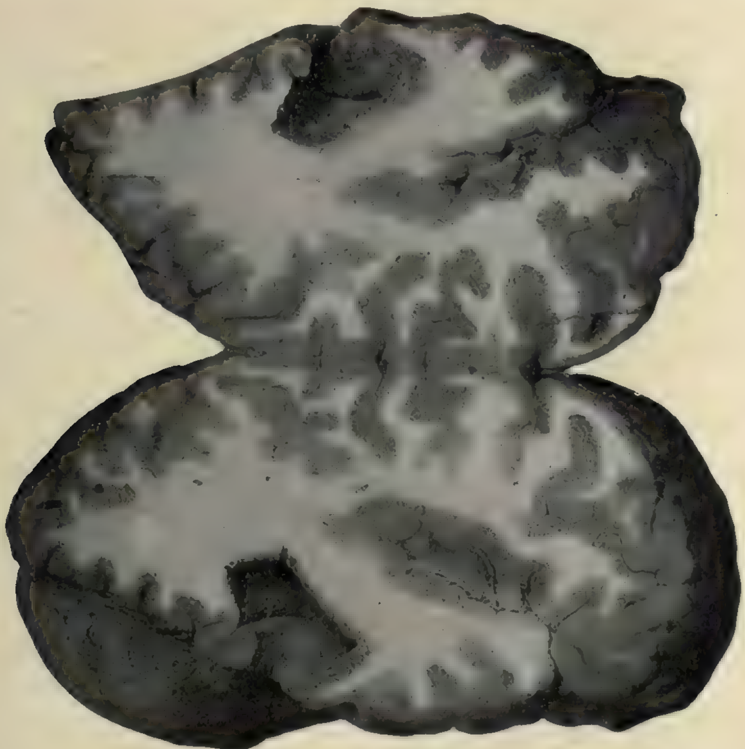

Fig. 46.—Abscess of Brain. (From Macewen's "Pyogenic Diseases of the Brain and Spinal Cord," Fig. 41, p. 94.) Brain in sagittal section, showing space left by encysted abscess in temporo-sphenoidal lobe. Note the neck-like opening at the base of the abscess, constituting, with the conical projection of the membranes (not seen in figure), a sort of stalk which represents the area of initial invasion. This is situated usually at the point indicated, that is, just over the anterior pole of the cerebellum.

sule may be so thick that the whole abscess may be shelled out. The effect upon the surrounding nerve tissue is often one of displacement, rather than of destruction, as is seen in the early recovery from paralysis after the relief of tension which operation affords.

Bacteriologically, the usual pyogenic organisms, staphylococci and streptococci, are the most frequently found; yet there have been recorded instances of infection with the pneumococcus, the ray fungus and other varieties of the streptothrix family, the B. typhi, the glanders bacillus, and others less well known. In old cases the pus may be found to be quite sterile, and its character may vary from that of a somewhat reddish thick material, not far removed from disintegrated nerve tissue, to that of foul greenish matter.

The relations of abscess to meningeal infection are interesting. One would naturally suppose that, with an extension from outside, the infection would lead primarily to a general or at least local meningitis before infecting the cerebral substance. Such, however, is a rare event, infection seems to spread more or less constantly directly through the meninges in a straight path, through the cortex and into the white substance, before it finds a soil ready to receive it favorably. The extent of its effect upon the meninges and cortex is to cause a localized proliferative inflammatory reaction, which results in the course of time in what has been called the "stalk" of the abscess, and is represented histologically by a fibrous cord. (See Fig. 46.) The white substance, whether from lack of abundant blood supply or from other reason, seems to offer much less resistance to bacterial action than the overlying structures. Thus, the abscess with its stalk resembles, as Ballance has pointed out, a mushroom. In the course of the disease such a subcortical abscess not infrequently breaks through to the surface, and this almost invariably causes fatal diffuse suppurative meningitis.

Symptoms.—The symptoms present great variety. There are several principles, consideration of which may help in the general understanding of the subject. In the first place we have to take account of the influence of site; that is, symptoms may have a focal character with regard to cerebral function; then we must remember the effects of general cerebral compression which the presence of an abscess causes; and finally also that certain of the symptoms are due to the general febrile disturbance belonging to the presence of infection in the system, whether this be chiefly the result of the cerebral infection itself, or of one of the general diseases which may give rise to cerebral abscess. The details of abscess as complicating otitic suppuration will be considered in another part of this volume. Here the subject will be discussed largely in its general aspects.

As regards the general symptoms of the infection and the course of the disease Brissaud and Souques have laid down five chief clinical types, the description of which I borrow from Ballance.

1. The subacute evolution, more or less definitely divided into three stages: (i) The initial febrile stage with headache, vomiting, and fever; purely general symptoms which may equally well belong to any specific fever. This period lasts from a few days to a week or more and is said to correspond to the acute stage of suppuration. (ii) The stage of remission, sometimes called the latent stage. The symptoms subside gradually and the patient seems to be on the road to recovery; nevertheless, as Ballance well observes, the latency of the period may

be more in the faculties of the observer than in the clinical reactions of the patient; and, as a matter of fact, if observation were sufficiently close and accurate, there can be small doubt but that some signs of the presence of the abscess would be discovered. (iii) The paralytic stage. This usually begins suddenly like a "stroke," with or without convulsion. This may pass shortly into coma and terminate fatally in a few hours, or it may temporarily be recovered from, and there will then remain probably symptoms indicating a focal lesion. The fever, which is usually present during the first stage and normal during the second, may rise again. If it does, it may indicate a rapid extension of the abscess, or else the incidence of a meningitis. In some cases, however, the contrary is true and the temperature becomes subnormal. In such it may be surmised that the fatal issue is caused more by acute compression, possibly a hydrocephalus, than by recrudescence of the infection.

2. The second class represents an evolution with severe general infection. These are rapidly fatal cases, high fever and acute delirium are present, and that is often practically all. Diagnosis is frequently quite impossible, beyond that of some acute specific fever. If localizing signs are present, or if some focus of suppuration elsewhere be found, one may go so far as to suspect strongly the presence of an intracranial abscess, but scarcely further.

3. In the third class the evolution takes place with complete latency, until the final attack of coma. The patient dies suddenly or in a few hours, and the brain abscess is an accidental finding at autopsy. Here most frequently the abscess is in a silent region, and the rapid, even sudden, death is probably due to pressure upon the bulbar centres. Such cases have long aroused particular interest because of their very unexpectedness, and they used to be considered as rather typical of cerebral abscess.

4. In the fourth type the clinical course is not distinct from that of brain tumor, and as a matter of fact the gradual increase in the size of the abscess, as the result of a low-grade infection, makes the conditions practically the same as those of a tumor.

5. The fifth variety of evolution is the remittent type. To quote Brissaud: "The clinical evolution is in two acts separated by an *entr'acte* of greater or less duration. The first act is marked sometimes by headache and fever, sometimes by an attack of mania, sometimes by acute delirium; then all quiets down, and the patient seems cured. After a few weeks, a few months, or even a year, follows the second act, which is commonly quickly fatal."

These general considerations upon the ordinary course of brain abscess give us, with the usual clearness and logic of the French mind, a very convenient panoramic view of the general course of the disease. There remain to be considered the symptoms as evidenced more particularly by the location of the abscess. It has already been said that there may be absolutely no focal signs, but even in such cases it is probable that signs of general pressure will be found, if sought for, in the way of headache of varying degree, of a general feeling of illness, possibly in a slight grade of optic neuritis. These symptoms, the condition being latent, are rarely looked for. If the abscess be situated in the frontal lobe, one may obtain the signs of loss of memory and change of character, which are not infrequently found in destructive lesions of that region. So it was in Borchhard's case, and in a patient of Dr. Bell's service observed by the writer. If such manifestations are present, they will usually be misinterpreted, if noticed at all, and the diagnosis when made will rest upon the development of motor symptoms, upon the gradual backward spread of the disease and the implication of the precentral convolution. If the abscess is situated in the temporal lobe, it will likewise frequently betray itself by no symptoms until, by pressure on the subcortical motor path in the corona radiata, motor symptoms develop. When the abscess is situated on the left side, it not infrequently causes a sensory aphasia of varying degree, chiefly word-deafness, occasionally combined with word-blindness from the posterior spread of the infection. In rare cases also the mesial surface of the lobe becomes involved, and, the centres of taste and smell being irritated, definite signs in this direction may be found, such as convulsions preceded by sensations of a foul odor or taste. Ballance has also observed cases in which the "dreamy" state described by Jackson, peculiar to temporo-sphenoidal-lobe lesions, was found. These are rare symptoms in temporal-lobe abscess, yet are extremely important in diagnosis when they do occur.

The abscess is quite frequently found in the cerebellum. Here the diagnosis may be extremely difficult, especially if the course is acute. The typical cerebellar signs, when present, are quite diagnostic, yet they are frequently lacking. Suboccipital pain, vertigo, ataxia, and what Trotter refers to as the characteristic "triad" of ocular signs—nystagmus, weakness of conjugate movements, and "skew" deviation—are characteristic, especially if there be present optic neuritis, though that is really somewhat infrequent. If these are all present the diagnosis of cerebellar abscess becomes fairly certain.

So many cases occur, however, in which these various focal signs are lacking that one is forced to the conclusion that diagnosis must in the last instance depend chiefly upon accurate history, the finding of a sufficient cause, and especially the location of such a cause. In the presence of acute signs of cerebral lesion possibly suggestive of abscess, if one finds a history of trauma, and particularly if that trauma has clearly resulted in a fracture of the skull communicating with the exterior; or if in the history there be found evidence of infection of the ear-apparatus, or of the frontal or sphenoidal sinuses, then the diagnosis of abscess must be considered as extremely probable. If, in addition to this, localizing signs being still absent, there develop symptoms of general cerebral compression, such as slow pulse, disturbed respiration, and a rise in blood pressure, the diagnosis becomes fairly certain. In the presence of a port of entry for the infection, sufficient evidence is present to justify exploration in the neighborhood of the original infection, usually one of the sinuses or a depressed fracture.

Differential Diagnosis.—This has to be made from acute encephalitis, meningitis, acute ependymitis with hydrocephalus, septic sinus thrombosis, and, rarely, a traumatic arachnoid cyst following injury. This statement applies to the more or less acute cases. In that of chronic abscess the differentiation has to be made from tumor. While in the majority of cases the history and the local findings will yield the diagnosis of abscess with moderate certainty, there are certain general principles which serve to separate these various conditions. Definite signs of general compression are apt to be lacking when the condition is one of meningitis, encephalitis, or septic sinus thrombosis, save in their terminal stages. The characteristic signs of root irritation, such as cervical rigidity and Kernig's sign, sufficiently distinguish meningitis. In sinus thrombosis there is a tenderness over the posterior part of the mastoid, and along the course of the jugular in the neck, together with an irregular septic fever. In thrombosis of a basal sinus, particularly the cavernous, no definite sign may be present but that of exophthalmos. When doubt still remains, a lumbar puncture may settle the question. In abscess the fluid is clear—that is, provided the abscess does not communicate with the meningeal space, while in meningitis there is an excess of leucocytes, whether mononuclear or polynuclear. The presence or absence of bacteria in the puncture fluid is also of assistance. In one instance the author has found particular difficulty in distinguishing between abscess and the arachnoid hæmatocele or traumatic arachnoid cyst of Prescott Hewitt, to which Ballance has lately called particular attention. The patient had suffered a fall two months previously; signs of general cerebral compression made their appearance at the end of the first month, and culminated in the eighth week with unconsciousness and hemiplegia. Here the indications which pointed to the aseptic hæmatocele, ultimately found to be present, consisted in the lack of any history of compound fracture, the absence of fever at any time, and the absence of leucocytosis. It must be admitted that these were not signs of any great value, and in such cases the diagnosis must halt between the two. As to fever, it is often found to be lacking in cases which pursue a subacute or chronic course; the same is true of leucocytosis. Nor does absence of compound fracture exclude the possibility of hæmatogenous infection.

In the otitic cases the occurrence of acute serous meningitis very frequently leads to an error in diagnosis; in fact, operations for the condition, as Koerner has well emphasized, are nearly always undertaken on the mistaken diagnosis of abscess. It is important to remember the possibility of this condition, in order during operation to recognize the futility of overgreat exploration of the temporal lobe, if upon opening the dura any material amount of clear serous fluid is evacuated.

Prognosis.—While the outlook for the unoperated cases of cerebral abscess is hopelessly bad, there has been a tendency, since the publication of Macewen's brilliant results, to consider that under operation the great majority of cases are saved. This is certainly an erroneous impression. It may be said of the operated cases, which after all represent to a certain extent the select class (those, namely, in which diagnosis can be made with some degree of likelihood), that not over half recover. Granted the diagnosis, there is, first of all, the frequently met difficulty, if not impossibility, of finding the abscess, the patient dying later of continued pressure. Then, in the second place, the fashion of bringing a case to the surgeon in the paralytic stage, or at least at a stage when signs of compression are at their height, furnishes another obstacle to success. And, finally, there are the difficulties inherent in maintaining drainage. Occasionally also there comes a case where one abscess is drained while another is unsuspected, the latter going on to cause death; or even a case in which there is what may be called a single abscess of dumb-bell shape, one end of which only is opened, while the drainage through the communicating handle of the dumb-bell proves insufficient to evacuate the other end. All these reasons illustrate the difficulty of securing good results.

Treatment.—The operation is quite ancient. The French surgeons of the eighteenth and nineteenth centuries seem to have incised the brain for abscess a number of times. (Petit, Boyer, and Dupuytren.) In operating for this condition success depends upon the pathological knowledge that the abscess in most cases will be found very close to the area through which the infection occurred, and upon the principle that the drainage opening must be made very free, and be thus maintained. With regard to the first there has arisen more or less discussion concerning the best way to approach the abscess. Generally speaking (for the moment it is a question of the otitic and the frontal-sinus abscess), the otologist prefers to follow along the track of infection, and he therefore first clears out the middle-ear and mastoid regions, and then follows any lead which he may find upon exposing the dura mater. There is much to be said for this position; and Ballance with his large experience has indeed said much for it. The advantages are that one approaches the abscess along its stalk; one is more certain to find it, and when found it is the more easily and effectively drained, and with the least danger, because of the adhesions that have formed, of infecting the general meningeal space. The general surgeon who, as a rule, is somewhat unfamiliar with mastoid operations, prefers to go in directly upon the presumed site of the abscess, through the squama of the temporal bone.

Each method has its indications; and yet it must be remembered that, if the direct route be chosen, there is sure to be left behind (in the otitic cases) a focus of infection which may prove fatal to the patient in some other way. In the obscure cases and in those in which the patient is in the stage of severe compression, it will probably be better to make a wide opening in the temporal bone in order to be sure of being able to make a thorough exploration, and also in order to afford decompression. The wideness of the opening also gives opportunity to pack off the surrounding meningeal space in order to prevent a spreading meningitis, and it also secures ample drainage. In the initial stage during the first few days, when it is still uncertain whether the symptoms may not be due to intense yet localized inflammation of the dura and of the leptomeninges, or possibly to the development of a localized serous meningitis, it will be best to do the otological operation, clear out the whole infection in the middle ear or mastoid, expose the dura, and drain for a day or two. Experience has shown that with the removal of the prime focus of infection, the cerebral symptoms often subside. If they do not, there should be no delay; the dura should be opened where it shows dark and inflamed (as it nearly always does), and the temporal lobe or the cerebellum, if the infection point that way, may be explored from below with a hollow needle or the knife. This procedure is perhaps also the best for the cases that are recognizable and come to operation in the latent stage. In cases of definite cerebellar abscess, it is undoubtedly best to follow the stalk of infection, and cut through the mastoid rather than to explore primarily through the suboccipital region. This gives one an opportunity of ascertaining the condition of the lateral and sigmoid sinuses, and of adopting appropriate measures if these vessels be found to be thrombosed.

To find the abscess, Ballance recommends the use of a long, narrow-bladed sharp knife; others use a hollow needle, blunt at the tip and with lateral openings so that the lumen may not be blocked by brain tissue. The writer thinks that an ordinary grooved director is as good as anything else for exploration. When once the abscess is found, the intervening brain substance must be cut, and the track dilated sufficiently to allow the introduction of a fair-sized drainage tube; and here comes the one serious difficulty in the after-treatment. Because of the nature of the tissue which is being drained, a semiliquid cerebral substance, the walls of the abscess are apt to fall in upon the inside end of the drain and block it. Also the general compression under which the brain may continue to stand because of local inflammatory reaction may force the latter, hernia-like, into the trephine opening, and extrude the drainage tube. Under such circumstances the danger of reaccumulation is certainly serious; even when the tube is kept in, pus may very soon cease to flow. Then further conduct will depend upon the patient's condition. If renewed signs of pressure develop, the wound must be immediately re-explored; and not infrequently this procedure will be rewarded by finding either retained pus in the cavity already opened, or else a second abscess previously unsuspected. Irrigation should not be employed.

That interference for cerebral abscess once diagnosed is a matter of emergency, no one will nowadays care to deny; too frequent have been the cases in which an operation fixed for the following morning has been forestalled by the sudden death of the patient during the night. The records of probably every hospital, if searched, would show instances of this sad event; and the lesson is obvious, that not alone should we operate immediately upon the making of the diagnosis, but we should operate without waiting for too exact a diagnosis. A reasonable suspicion of the presence of cerebral abscess upon competent observation justifies an exploratory operation. Better to explore and fail than not to have explored at all. Even in the paralytic stage of compression, and in the presence of sudden respiratory failure on the operating table, patients have been saved; Cushing, Horsley, and Rawling have reported such cases. The necessity of having at hand an artificial-respiration apparatus for such eventualities is justly emphasized by the former.

Here, doubtless, as in all branches of medicine, the ounce of prevention is worth the pound of cure, and the necessity of early and radical operation in the infections of the various accessory sinuses should be more widely recognized even than it is. The otologists have long understood this, but it has needed the strong words of Killian and of Ballance to emphasize the equal necessity of such interference in cases of frontal and sphenoidal sinus suppuration.

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Hemorrhages in the Cerebral Substance.

Intracerebral hemorrhage may be due to trauma or to vascular disease. In the first case it may be cortical, and is then situated very frequently at the base in the posterior frontal and anterior temporal regions. Hemorrhages in these localities have been already sufficiently discussed elsewhere. Or, again, the hemorrhage may be situated underneath the cortex, in which case it may lie anywhere in the brain, although probably more frequently in the centrum semiovale than in the basal ganglia and stem. (See Fig. 47.) Hemorrhages may be single or multiple. The violence is either indirect, as with the bursting fractures, or direct, as in the depressed and punctured fractures, the shot and stab wounds. In the latter instances, of course, their situation is determined by the nature of the accident. Intracerebral hemorrhage of any size is relatively infrequent as compared with meningeal bleeding. In fifty autopsies on cases of fracture of the skull I found only four instances, while meningeal effusion was practically constant. The actual amount of the hemorrhage is a mere matter of accident. At this point may be recalled the condition of traumatic "late apoplexy," which receives separate discussion.

When vascular disease is responsible for intracerebral hemorrhage, the latter is usually dependent upon the rupture of a miliary aneurism; and, as is

FIG. 47.—Right Hemisphere of Brain Sectioned Horizontally, to Show Large Subpial and Cerebral Hæmatoma in the Prefrontal Lobe, the effect of contrecoup from a fall on the head. (Pathological Department, Royal Victoria Hospital, 86, 1903.)

well known since Charcot's pronouncement, it is most often the lenticulo-striate branch of the middle cerebral that is involved. On the other hand, hemorrhage may occur in the centre of new-growths, especially the gliomata and the vascular sarcomata. Doubtless the cystic degeneration which is so frequently observed in these tumors is partly hemorrhagic in origin. Such a hemorrhage may be sudden and give symptoms resembling those of a stroke of apoplexy. (See Fig. 68.)

The symptoms of the traumatic hemorrhage are chiefly, on the one hand, those of concussion and, if the clot be large, of general compression variously intermixed. These have been discussed elsewhere. On the other hand, there are all those symptoms which are dependent on localized interference with nerve function. For the details the reader may consult the section on Cerebral Localization. When the hemorrhage is spontaneous the well-known hemiplegia with unconsciousness constitutes the chief sign; but a detailed consideration of this matter must be sought in books on internal medicine. What concerns us here is chiefly the question of surgical intervention.

(1) **The Traumatic Cases.**—A traumatic intracerebral hemorrhage may give localizable signs, and these will most often be motor. Under such circumstances, operation will usually be undertaken under the diagnosis of middle meningeal hemorrhage. This not being found, the dura will be opened, and, if still no blood collection be discovered, the usual course of the operator will be to close the opening in the membrane. There are one or two observations which seem to indicate that such a decision is a mistake, and that it is wise—it being granted that the focal symptoms are definite—to explore the brain for a subcortical clot. The well-known case of Borsuk and Wizel is illuminating in this respect.

A man had received a blow with a stone on the left side of the head. His primary unconsciousness soon gave way, and he came to hospital with little more than a headache. The next day he was conscious, but complete aphasia had developed. Operation at this time removed depressed bone and blood-clot, the dura being quite intact; it was thought that this had been the sufficient cause of the aphasia, yet on the next day there was no improvement. On the third day after operation the right arm became paretic, and in the evening a Jacksonian fit occurred involving face and arm. By the sixth day complete hemiplegia had developed. Fits had become so frequent as to constitute status epilepticus, the patient was unconscious, the pulse rapid, the temperature high. Operation revealed, after reflection of the dura, a normal brain surface. Borsuk, undeterred by such negative findings, made exploratory punctures, and, going through the posterior central convolution about on a level with the face centre, got bloody fluid from a considerable depth. He then cut in at this point, and emptied two drachms of blood-stained fluid enclosing clots. The next day unconsciousness and hemiplegia disappeared, the patient began to speak, and from this time on rapidly recovered.

Such a combination of circumstances, it is true, will not often be found; yet the surgeon must be cognizant of the possibility of their occurrence and be prepared to meet the indications.

Where the injury has been a direct one, as in Cushing's case of stab wound of the post-central convolution, the indication for operation and its performance are comparatively clear and easy. These cases teach us that the severe loss of function (aphasia, hemiplegia, etc.) is frequently not due to the actual destruction of nerve tissue, but to pressure of effused blood or of the œdema which naturally develops as a reactionary process within a few hours. In an instance observed by the writer, in which there was a punctured fracture through the orbital roof, caused by a small bamboo rod (as used in the game of diabolo), the almost complete aphasia and hemiplegia which developed within a few moments of the accident disappeared almost entirely in the course of a few weeks, leaving nothing but a very slight contraction of the arm.

(2) **Spontaneous Cerebral Hemorrhage.**—While in a great many respects the idea of evacuating the clot in cases of capsular hemorrhage (cerebral apoplexy) seems thoroughly rational, it is only within the last few years that the attempt has actually been made to carry it out. As early as 1890 the question of surgical interference had been raised by Horsley, who deprecated a direct operation through the cerebral substance for this purpose, and recommended ligature of the common carotid artery. This procedure has never commended itself to the profession at large. Hill in 1896 recommended, on theoretical grounds, large openings of the skull for decompressive purposes and for the possible removal of the intracranial clot. In 1897, Borsuk, upon the basis of his successful operation, which has been recounted, suggested that a similar procedure would be of advantage in medical cases. Lambotte actually operated for the removal of a capsular hemorrhage of one month's standing in a very feeble, old man. He removed a certain amount of pale blood-stained fluid, but the patient died a few hours later. This seems to have been the first operation deliberately done for this condition. Finally, in 1902, Harvey Cushing published the details of a case in which he had evacuated a clot, the patient, after a very definite improvement, dying on the third day from pneumonia. Quite recently Cushing reports the mere fact of having operated up to the present four times for this condition, and of having saved one patient. It must be remembered that in these instances operation was undertaken as a last resort. The question is still very much *sub judice.* On the medical side, it is certain that no active therapy is possible. Venesection, so frequently done in the past, is certainly apt to be harmful, and at the best is useless, as Cushing has demonstrated both experimentally and clinically by means of blood-pressure observations. When therefore the patient is about to die, it is justifiable at least to weigh carefully the question of surgical interference. In an analysis of the cases of apoplexy in the Royal Victoria Hospital (which my house surgeon, Dr. Patterson, has kindly made for me) I have found certain facts of interest in this matter. Of 27 acute cases admitted, 24 died and 3 recovered. The mortality, therefore, at least among hospital patients, is very high. In 15 of these a post-mortem examination was obtained. It was apparent that in 7 death had been due to the effect of compression alone. In these the time from onset of the attack to death varied from two to twenty-seven hours. In 4 others the cause of death seemed to be chiefly pneumonia; and these died from the fifth to the fourteenth day after the onset. In the other 4 death seemed to be due to the combination of pneumonia with compression, and these died during the first week. It is thus evident that if death is to be warded off by operation, two indications have to be met—in the one, compression alone, in the other, a complicating pneumonia. As to the situation of the clot, it was clear, surgically speaking, that operation was possible in 2 of the 7 cases of pure compression. In

the other 5 it was contraindicated by a rupture into the ventricles or by the overwhelming nature of the hemorrhage, with very early death. (See Fig. 48.) In the rest of the cases, where death was due to pneumonia chiefly or to this disease in combination with compression, operation would seem to have been possible in 3; in 3 others the possibility of benefit was doubtful; and in 2 operation was decidedly contraindicated.

As to the diagnosis of serious compression, the one remarkable point was that a really slow pulse was rare; only one instance of a pulse below 60 was found, while in

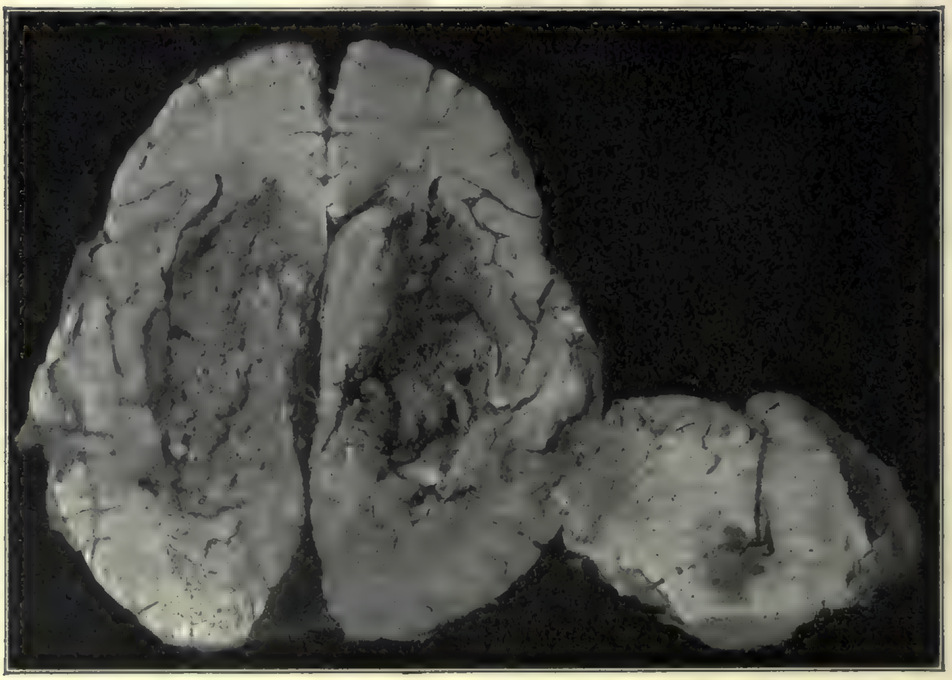

Fig. 48.—Right Hemisphere Sectioned Horizontally, to Show the Extensive Destruction of Brain Tissue Caused by a Cerebral Hemorrhage, and the considerable depth from the cortex at which the effused blood may lie. On the right are seen the cerebellum and pons of the same case in vertical section, showing hemorrhage in and around the floor of the fourth ventricle. (From the Pathological Department of the Royal Victoria Hosp., No. 72, 1905.) This patient died within a few hours of the onset. The specimen illustrates the overwhelming nature of the hemorrhage in some cases, for which surgery can do nothing

six its lowest rate was between 60 and 70, and in the others between 70 and 80. In the rest it was above this figure. Therefore, at least during hospital stay, the pulse has run in the majority of instances at a fairly normal rate. Observations upon blood pressure have hitherto been lacking. However, the high-tension pulse as measured by the finger is very frequently mentioned, as also the deep and irregular respiration of cerebral compression. The lesson is, if one is thinking of surgical interference, not to rely upon a slow pulse for the diagnosis of severe and advancing compression. There was found intraventricular blood in five out of fifteen. From these considerations it is evident that operation when undertaken, at least in the later stages, must very frequently be unsuccessful, on the one hand because of the frequency of complicating pneumonia (see Fig. 49), which in very many cases is already present at a time when operation is resolved upon, and on the other hand from intraventricular hemorrhage. The frequency of pneumonia as the essential cause of death, a pneumonia which is certainly an inhalation one and ascribable directly to the patient's unconscious condition, suggests really the question of the advisability of surgical interference

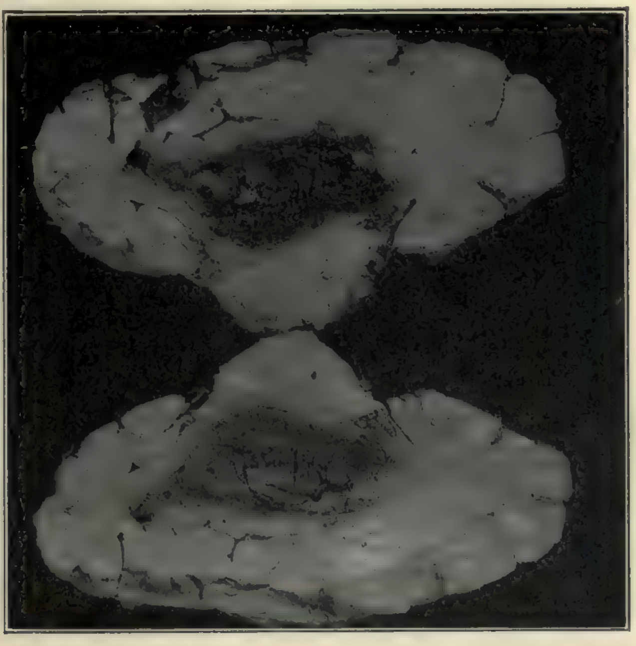

Fig. 49.—Horizontal Section of Left Cerebral Hemisphere in a Patient who Died eight Days after an Apoplectic Stroke. The blood was effused into the internal capsule and extended into the brain substance under the floor of the left lateral ventricle. The lowest rate of pulse was 76, and of respiration 22, both three days before death, and the chief cause of death seems to have been an acute terminal broncho-pneumonia. With regard to the possibility of operation, one has to note on the one hand the depth of the clot from the surface, on the other hand the lack of the usual bedside symptoms of slow pulse and irregular respiration (compression), and finally the so frequent complication of pneumonia as the cause of death. (See text.) (Med. Case Reports 7648. Path. Dept., R. V. H., 16, 1903.)

even in the cases that are not in a desperate condition from mere compression, provided they are deeply unconscious, with the object of relieving compression at an early date and possibly restoring consciousness. If the patient were conscious he would certainly much more rarely develop pneumonia; and any argument based upon the danger to life of operation cannot have great force in the face of a mortality of twenty-four out of twenty-seven under expectant treatment. These remarks naturally apply, not to the clinically mild cases in which the idea of intervention never occurs, but to the serious cases showing all the classical signs of the apoplectic stroke.

These indications, however, being admitted, certain questions arise and must be answered. Is the condition susceptible of being certainly distinguished from embolism? Does the blood clot early? Is hemorrhage really ingravescent, or is the increase of symptoms due, as Cushing thinks, to the development of collateral œdema? If the clot be evacuated will bleeding be resumed? Is the operation very serious in itself? And granted the possibility of saving life, is it worth while, with left-sided effusions involving aphasia, to save such a life? The only man who can answer these questions on the basis of experience is Harvey Cushing. His opinion is decidedly in favor of the operation in selected cases. He argues that, because it is the collateral œdema which is responsible for many of the paralytic symptoms, ultimate recovery of function may be secured, and will then be greater than if nature is left to absorb the clot unaided. This, of course, apart from the main indication of saving a life which is threatened by pure compression. He finds the indication for operation in the presence of the acme stage of compression with evidences of arhythmicity in blood pressure and respiration. Such a condition is critical and in all likelihood will go on to death. The operation which he advises consists in a large subtemporal removal of bone, with an exploration high up in the opening, just above the Sylvian fissure, in order to escape wounding the insula, and through the posterior central convolution. The cavity once opened, the clot will extrude itself. The opening is then enlarged and a soft-rubber tube is left in for several days.

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Late Post-traumatic Apoplexy.—To Bollinger we owe the definite knowledge that the small localized lesions in the cerebrum, of laceration or hemorrhage resulting from concussion, may, through consequent softening, give rise to cerebral hemorrhage, a hemorrhage that comes on days, weeks, or even a few months after the injury, and which he therefore called late apoplexy (Spätapoplexie).

The pathological explanation assumes an advancing degeneration of the walls of vessels in or near the focus of softening, a condition sufficiently proved by Schmaus to exist.

The symptomatology is indicated by the name. It is an apoplexy, although frequently it has the character of the ingravescent form, with prodromes consisting of headache, vertigo, noises in the ears, etc., which may appear a day or two before the ictus. The outlook is most unfavorable; almost invariably the patients die within a few days.

The subject of diagnosis has aroused much discussion. There must be naturally a history of trauma, but Langerhans, in 1899, has denied *in toto* the existence of apoplexy as due to trauma in Bollinger's sense, and Israel is inclined to the same view. The standpoint adopted by most writers lately is that the condition exists, but is rare; and that for its diagnosis, clinically and pathologically, it is necessary that the patient should have been previously in perfect health; should show no signs of arteriosclerosis, nor have suffered from lues, cardiac disease, or alcoholism. Under such conditions as these the likelihood of the presence of ordinary causes of spontaneous cerebral hemorrhage is so great that it is impossible to give to a preceding trauma any positive value as a causal factor. Medico-legally, as is evident, these somewhat theoretical considerations become of considerable practical importance.

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XVI. LOCALIZATION OF CEREBRAL FUNCTION.

From Flourens, who nearly a century ago taught that it was not the site but the extent of a cerebral lesion that influenced the nature of the resulting symptoms, to the present day, when the whole cortex is divided like a county map into a large number of separate areas, each with its more or less independent function, is a far cry. The colossal amount of work done in this interval, chiefly in the last fifty years, upon this subject, is a monument not alone to the ingenuity, but also to the industry, of the workers in medical science. We have no space here to trace in detail the steps of this march of conquest. In all essentials, Broca was the leader. Less than fifty years ago (1861) he showed that the seat of voluntary motor speech lay in the convolution which has since been called for him. In the following decennium, Hughlings-Jackson and Bastian by clinical observations, and Fritsch and Hitzig by laboratory experiments, mapped out roughly the motor area. Then came Ferrier and his successors of the great English school, Sanderson, Schaefer, Horsley, Spencer, Mott, Sherrington, and Gruenbaum, with Munk and Schiff in Germany, and many others, working chiefly along the lines of electrical stimulation and of axone degeneration following extirpations; Flechsig along the line of embryological development; and Meynert, Betz, Golgi, Ramon y Cajal on the minute cerebral structure, whose labors, in so far as they bear upon localization, have culminated in the last few years in the splendid work of Campbell and of Brodmann.

All this time the knowledge of the subject has been advanced perhaps as rapidly by the investigations of the clinician-pathologist as by those of the physiologist. Many things, otherwise undiscoverable, have been established by the careful correlation of symptoms with pathological findings, as exposed, not alone at post-mortem examination, but also at operation. Within the last score of years certain surgeons whose studies and opportunities have fitted them to appreciate the problems of neurology, and who have worked largely hand-in-hand with the neurologist, have contributed greatly to the knowledge of the subject along the lines of scientific physiology. First and foremost among them are Macewen and Horsley in England, Keen in America, Krause in Germany, Durante in Italy, Duret and Chipault in France, and lately Harvey Cushing and Frazier on this side of the Atlantic. For the future a great opportunity lies before the trained neurological surgeon in the way of scientific work. The best will be accomplished by the collaboration, not of the neurologist with the general surgeon acting as his carpenter, but by the neurologist with the neurological surgeon acting as his team mate.

The Cortical Centres.—It is necessary to remember in a general way that, as physiologists now emphasize, the so-called centres situated in the cortex are not, as it were, terminals that originate, but rather stations or junctions that elaborate and pass on; and that in this sense they form a very important part, it is true, yet only a part, of the great reflex system.

THE EXCITO-MOTOR CORTEX.—In spite of the remark of Hitzig, who with Fritsch in 1874 was the first to work upon the electrical reactions of the cerebral cortex, that "the pre-central convolution was the true or proper motor part of the cerebral cortex of the monkey," the conception became and remained general that the post-central as well as the pre-central convolutions contain centres the stimulation of which gives rise to contra-lateral muscular movements. Indeed, so late as six or seven years ago nothing seemed more definite than this; not alone from physiological experiment but also from clinical observation. The reason of this error—for we now feel sure that it was an error—is probably to be found in the fact that the early experimenters used a bipolar electrode and too strong a current, so that the electrical impulse was widely diffused; and on the other hand that clinical lesions strictly confined to the one or the other convolution have been very rare. In 1901 Sherrington and Gruenbaum published their remarkable experiments upon the higher apes, which demonstrated unequivocally that the motor cortex was absolutely confined to the anterior central convolution and to the pre-central side of the Rolandic sulcus as far as its bottom. At this point there was a sharp line of demarcation separating it from the sensory cortex. In no long time these observations were confirmed for man in two ways—by faradization of the human cortex and by histological study.

In 1903 Krause of Berlin, during the course of various operations upon the cerebrum and using a unipolar electrode after Sherrington's example, was able to demonstrate a location of the motor centres practically identical with those got by Sherrington in the ape; while Brodmann in the same year adduced histological evidence to show that the minute architecture of the cortex of the pre-central convolution was entirely different from that of the post-central. In 1905 A. W. Campbell published his splendid work upon cerebral histology, which not only confirmed these findings as to the motor tract, but also enabled him to map out the cortex over the whole cerebrum into various areas, which histologically corresponded more or less with variations in function as demonstrated or guessed at by physiological methods. Finally, in the last few years Frazier, and particularly Harvey Cushing, have by numerous faradizations of the human cortex during operation, amply confirmed these general conclusions and elaborated them.

The motor cortex therefore in the human being, as we know to-day, occupies a narrow strip of the pre-central convolution, not its entire width by any means,

Fig. 50.—The Motor Area of the Human Cerebrum as Defined by Electrical Excitation. (See text.) (C. K. Mills and Charles H. Frazier, *Univ. of Penn. Med. Bull.*, July–Aug., 1905.)

together with the surface that forms the anterior boundary and part of the bottom of the central or Rolandic fissure. Its limit posteriorly is sharply marked; anteriorly it shades off indefinitely into the posterior frontal area. From below it extends from the posterior part of the third frontal convolution and the lower limb of the Rolandic fissure upward to the longitudinal fissure and down over the edge, taking up a certain area of the mesial surface, the extent of which is not yet accurately known, but which probably does not extend down so far as the calloso-marginal fissure. The illustration of Mills and Frazier here reproduced is the result of their combined investigations. (Fig. 50.) The Rolandic fissure, however, instead of being a nearly straight line, as it is here indicated for the sake of simplicity, should show two or three genua. These genua are important for surgical orientation. The superior one lies opposite a rather narrow portion of the pre-central convolution in which lie the centres for the trunk muscles. Above it is a somewhat triangular area running up to the longitudinal fissure and holding the centres for foot, knee, and hip; this is the leg area. Below this genu the cortex contains, from above downward, centres for the shoulder, elbow, wrist, fingers, and thumb. In front of the area just mentioned, that is, in the posterior part of the second and third frontal convolutions, experiment has sometimes demonstrated a centre for the conjugate movements of head and eyes; and in the upper posterior part of the second frontal convolution there is also situated a centre for motor memories of a particular kind, namely, those for word-writing. This is now fairly well established on the basis of clinical and pathological evidence. Between the arm and face areas Cushing has demonstrated a narrow strip subserving the movements of the neck muscles; and opposite this narrow strip is situated the inferior genu of most authors, or the middle genu of Cushing. Below this come centres for the movements of the eyelids, the angle of the mouth, the jaws and the platysma, the lips, tongue, and larynx.

The respective situations of these last foci are not quite agreed upon. The inferior genu of Cushing separates the centres for the upper face, eyelids, nose, and lips from those of the lower part of the face, including the jaws, tongue, palate, and larynx. Anterior to these latter is Broca's convolution or the posterior part of the third frontal, which is the centre for voluntary speech; and Cushing has found, still lower, just above the Sylvian fissure, a centre for the vocal cords.

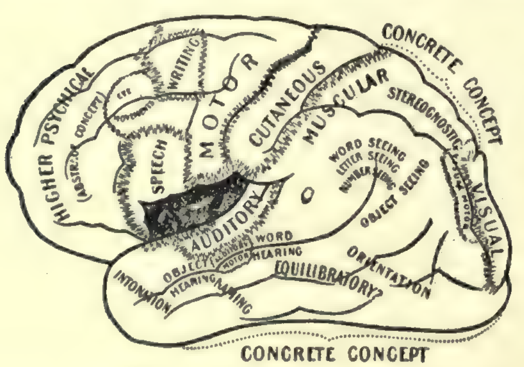

FIG 51.—Areas of Localization on the External Surface of the Human Brain. (C. K. Mills, *Univ. of Penn. Med. Bull.*, 1904.) Of these the centres marked "orientation," "equilibratory," "intonation" are still somewhat uncertain in man.

The absolute situation of all these centres is apparently not quite fixed. Doubtless there is need of a standard in measurements from any given point or points to serve as a basis for common observation. The genua of the Rolandic fissure in the mean time form our best guide for the gross location of the areas during operation. All this area is purely motor, its extirpation does not affect sensation. The fibres running from it to form the pyramidal system pass through the corona radiata, internal capsule, the crura, pons and medulla, and so into the spinal cord after decussating to the opposite side.

THE AREA OF THE CORTEX CONCERNED WITH SENSATION.—It is clear that not much can be learned from experimentation on animals as regards sensation. Still, there have been accumulated sufficient evidence of a histological nature, both normal and pathological, and sufficient clinical evidence, to give us the gross limits of the cortical sensory field with a reasonable approach to certainty. What is perhaps best established so far is the fact that the posterior central convolution is the receiving-station of the afferent impulses of ordinary tactile sensation. (See Figs. 51 and 52.) Campbell's researches again, in particular, have demonstrated a minute architecture entirely different from that of the motor cortex, and also definite alterations in the cortical cells after injuries or diseases which affect the peripheral sensory fibres, such as amputations and locomotor ataxia. Its anterior border, like the posterior limit of the motor region, is very definite. It begins in the bottom of the Rolandic sulcus, where the motor area ends; posteriorly it occupies half or more of the exposed surface of the post-central convolution. This area at least is devoted to the perception of the primitive sensation of touch. Its independence of the motor zone is further evidenced by the fact that lesions confined to it are not followed by degeneration of the pyramidal fibres.

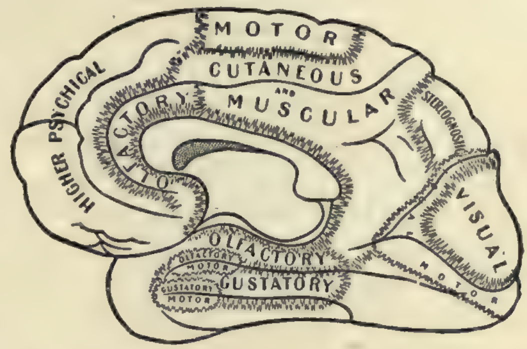

FIG. 52.—Areas of Localization on the Median Surface of the Brain. (C. K. Mills, *loc. cit.*) Note that of these areas, as indicated schematically here, the only reasonably certain ones are the motor, visual, olfactory, and gustatory. The rest have not been proved for man.

The sensory fibres in general from the peripheral system and the spinal cord, passing up in the fillet, arrive at a relay station—at least most of them do—in the optic thalamus,—and from here pass on in what has been called the cortical fillet, through the posterior part of the internal capsule, to end in the cortical cells of the posterior central convolution.

The forms of sensation to which we have just referred are primitive. Sensation, however, as perceived, may be very complex; in particular we have to take account of the muscular sense which gives us complex conceptions of weight or pressure and the position of joints at any given moment. And we have also to consider the stereognostic faculty, a still more complex affair, which represents memory pictures of objects such as we have learned them to be by a long education through a number of our senses, probably indeed all of them to a slight degree; chiefly, however, through tactile, muscular, and visual sensations. Stereognosis enables us to assert the nature of an object held in the hand while the eyes are closed. These more complex sensations are not represented in the posterior central convolution, but behind it. The muscular sense, it is true, probably occupies the posterior part of this convolution; but the area for those memories which give us our stereognostic sense is situated farther back in what was called by Flechsig the posterior association area, and chiefly in the superior parietal lobule.

The area of sensation from below upward extends from a point opposite the motor face area at least to the longitudinal fissure; and it probably occupies part of the mesial surface also. In a general way, sensation in any given part of the body, according to Mills, is represented in the cortex about at the same level at which is situated the motor centre for the corresponding part of the body. Thus sensation in the legs lies high up opposite the motor leg area, and so with the other divisions.

As far as we know, then, at present, tactile impressions are received in the post-central convolution near the fissure, those of the muscular sense probably just behind these; a little farther back in the parietal lobe are probably found those of pain and of temperature, that is, in the intermediate post-central area of Campbell (though this is uncertain), while still farther back yet, and confined to the superior parietal lobule, lies the representation of stereognosis. In other words, the elements of sensation lie near the Rolandic fissure, while the more complex combinations lie farther back. Clinically, a lesion of these areas causes a loss of sensation, which is in a characteristic way most marked at the periphery of the limbs and diminishes as one approaches the trunk; a loss, moreover, which is not confined to any one surface, but involves the whole circumference of the extremity.

The Cortical Area Concerned with Vision.—The perception of primitive visual sensations fresh from the retina is unanimously considered to take place in the calcarine region on the mesial surface of the occipital lobe; that of color is believed to lie just below this in the lingual lobule, extending somewhat upon the tentorial aspect of the lobe. The higher visual psychic area, where the primitive optic sensations are elaborated, occupies probably a large part of the occipito-temporal cortex—according to Mills, all the occipital convolutions together with the posterior extremity of the adjoining temporal convolution, chiefly the *pli courbe* or angular gyrus; all these, however, on the left side only, or chiefly. In the *pli courbe* there are, in particular, stored the memories of seen words, letters, and numbers, and these form part of the speech mechanism. (See Figs. 51 and 52.) Mills believes that the centres for the memories of persons, places, and natural objects lie somewhere in the rest of the lateral occipital lobe. A lesion of the corresponding areas of the right side causes few, if any, symptoms.

The Cortical Area Concerned with Hearing.—The elementary auditory sensations are received in the superior temporal convolution, and chiefly in its posterior part. They are elaborated into concrete memory concepts, in particular those of spoken words, of music, and of tones in general, in the adjoining parts of the temporal lobe. The representation is chiefly left-sided. A lesion of the right side remains without symptoms, and the reader may be reminded that it is the right temporal region which is now most frequently chosen for decompression as being a silent region. Mills places the centre for word-hearing at the junction of the first and second temporal convolutions posteriorly, and that of intonation more anteriorly in the same convolution. (See Fig. 51.)

THE CORTICAL AREAS CONCERNED WITH SPEECH.—Speech physiologically considered consists of four distinct functions. There are, first, the understanding of the spoken word, or word-hearing; second, the emission of the spoken word, or word-saying. These two represent Wiley's "primary couple" and are possessed by all individuals who have the power of speech in its common sense, that is, of articulate speech. There are gradually developed, however, in the educated, two others, "a secondary couple," centres which appeared in the course of evolution when man learned to express himself by written symbols. Thus, thirdly, the understanding of written symbols, or word-seeing; and, fourthly, the emission of written symbols, or word-writing. This last is still not absolutely established as a separate centre, although the tendency is to believe in its existence. All these centres, of course, represent merely areas of the cortex in which are stored the memories of the various motor or sensory symbols concerned with speech, as received or emitted, that is, sensory or motor. Concerning their situation, it is to be noted that each lies near the corresponding centres of perception for the elementary or primitive impulses, whether of sense or of motion. The word-hearing centre, involving the recognition of spoken words, lies in the posterior part of the superior temporal convolution on the left side; the motor or vocal speech centre for word-saying is in Broca's convolution, the posterior part of the third frontal; the visual word centre, that of word-seeing, lies undoubtedly in the *pli courbe* or angular gyrus near the visual psychic field; and, finally, the word-writing centre is believed to be situated in the posterior end of the second frontal, just in front of the primary motor centres for movements of the hands and fingers. (See Figs. 50 and 51.)

It must be realized that all these focal areas are most closely interconnected, and that it is very rare for any one of them to be affected without the others suffering. They form a chain which can hardly spare any one of its links.

THE OLFACTORY CORTEX.—It is generally believed that the chief cortical centres for the primary sensations of smell lie in the hippocampal lobe and especially the uncinate gyrus. More than this we do not know. The writer has seen an instance of traumatic cyst of the temporo-sphenoidal lobe formed around a spicule of bone driven in as the result of a fracture, which had brought on epileptic attacks with an aura constituted by disagreeable sensations of smell. The lesion extended deeply, presumably as far as the hippocampal lobe.

The *representation of taste* in the cortex is not known certainly, although the evidence points to its being situated also in the hippocampal lobe near the olfactory centre.

THE ASSOCIATION AREAS OF THE CORTEX.—These represent such areas of the cortex as have not been here detailed and are concerned with the process of associating the various concepts obtained by the functioning of all the centres already described. Flechsig believes that in them go on the higher and more complex mental processes, that they are the "true organs of thought." Surgically, they are silent areas save in the left pre-frontal region which is now believed to be principally concerned with the higher intellectual and psychic life.*

XVII. SYMPTOMS OF ORGANIC CEREBRAL LESIONS IN GENERAL.

Symptoms arise by interference of any sort with all these centres just described and are in many books embodied in the chapter on cerebral tumors. Indeed they have been worked out chiefly by the clinico-pathological examination of cases of tumor. It must not, however, be forgotten that trauma, besides other non-neoplastic lesions with which the surgeon has much to do, will produce the same symptoms as does tumor. It will therefore be best to precede the special discussion of cerebral lesions with a consideration of the symptoms of organic cerebral disturbance in general. A little repetition is unavoidable.

It may be said that these symptoms, at least those with a surgical bearing, are dependent in the main upon compression of the brain, whether that compression be local or general, whether it be sufficient merely to irritate or go on to paralyze and destroy, whether it merely inhibit temporarily the function of nerve fibres and cells or actually destroy them. There is of course a less frequent class of lesion, causing, however, the same symptoms, and represented by the incised or punctured wounds. In a general way, then, the symptoms may be irritative or paralytic, general or focal, acccording to the degree of compression. From another point of view they may be subjective or objective. Yet a prime fact is that, no matter what the nature of the compressing object may be, whether tumor, abscess, inflammatory infiltration, cyst, or clot, the symptoms in the ultimate analysis remain the same, even though they may vary in minor particulars.

General Symptoms.—The general symptoms of cerebral lesions, in so far as they affect by compression the bulbar centres, have been discussed in the section on Compression. Here we shall refer to certain others usually recognized as indicating intracranial tension—viz., headache and vomiting. The consideration of optic neuritis is deferred to the section on Tumors.

Headache.—Headache has for long been believed to be dependent on disease in or tension of the dura mater. In view of the late observations of Heidenhain and Cushing, who both have incised the dura in the conscious patient without

* Extensive bibliographies for the subjects of this section may be found in von Monakow's recent summary in the Ergebnisse der Physiologie, Sechster Jahrgang, and in the works of L. Bruns, "Die Geschwülste des Nervensystems," 2d ed., 1908, and Oppenheim, "Die Geschwülste des Gehirns," Nothnagel, Bd. ix., Abth. iii., 2d ed., 1902.

pain, it is probable that we must modify this conception. Probably it is chiefly distention or distortion of the membrane, and especially of the falx or tentorium, that is the chief cause of pain, rather than actual injury in the absence of tension or inflammation. In the brain cortex itself there is certainly no sensation. Mitchell and Cushing have both lately recorded instances of operations upon the cerebral substance without an anæsthetic and without pain. Whatever its cause, headache is an almost constant accompaniment of any meningeal inflammation and of all forms of increase in intracranial tension. Its situation is not of use in diagnosis, except that in the case of subtentorial growths it is rather characteristic to find pain in the occipital and upper cervical regions. This, however, is also seen in frontal tumors. It gains in value when confined to a limited area, over which there is tenderness on pressure. In such cases indeed it is most significant. Its intensity in many instances of acute hydrocephalus, of meningitis, and above all of tumor, is sometimes very great, defying all remedies; and its immediate and complete relief by operations that relieve tension is correspondingly striking.

Vomiting.—A type of cerebral vomiting is well known. It is often independent of meals and is projectile in character. It appears usually in any condition where intracranial tension is rapidly increased. Vertigo, apart from its definite causation from the labyrinth, is also a purely general symptom due to increased intracranial tension.

Focal Symptoms.—In the previous description of the various cortical centres concerned with localization their functions have been partly indicated. We have now to describe in slightly greater detail, although naturally it is impossible in a work of this character to give more than brief indications, the focal symptoms which characterize lesions of these centres and of other portions of the brain in so far as they have any surgical bearing.

Lesions of the Pre-central Convolution.—Irritative lesions of the motor tract in a general way induce over-action; and this is evidenced by tremors, twitchings, and the various convulsive movements which may culminate in the outspoken attack of genuine epilepsy. These various disorders of action, beginning in one point, may be confined to that region, may spread to neighboring muscle groups, to the whole of one side of the body, or, finally, may involve ultimately the musculature of the whole body. When such epileptic convulsions are found to begin always in the same muscle or group of muscles, and to preserve the same order of progression, the evidence is strong that the causal irritative lesion is situated in the cortex and particularly in that part of the cortex which represents the centre for the movements which initiate the attack.

The cause may be one of many lesions, a tumor, a clot, an abscess, meningeal adhesions, a cyst, or a foreign body. As a general principle the more outspoken the signs of irritation the more certain is it that the cortex is affected. Subcortical lesions, if deep, do not often cause epilepsy of the Jacksonian type.

Lesions of a more severe nature cause paresis or paralysis of the contra-lateral musculature, except where the latter is represented bilaterally in the cortex (larynx, thorax). The nature of the paralysis varies of course with the degree of the lesion, but chiefly with its situation in the motor tract. In this regard the essential diagnostic points are well illustrated in the accompanying figure from Allen Starr. (Fig. 53.) A lesion in the cortex rarely causes anything more extensive than a monoplegia. If in the capsule, or in the crus, where the pyramidal fibres are close set, it is equally rare to see anything less than a hemiplegia. Crossed or alternating paralysis is a characteristic symptom-complex where the lesion is situated in the pons; it indicates pressure upon the fibres supplying the muscles of the opposite extremities, and the peripheral course of the facial on the same side. The details are illustrated in Fig. 53.

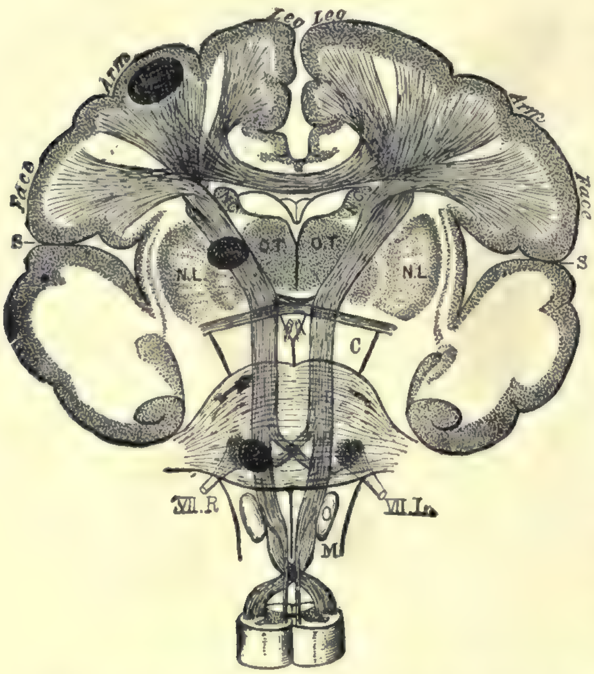

FIG. 53.—The Motor Tract. *S*, Fissure of Sylvius; *N.L.*, lenticular nucleus; *O.T.*, optic thalamus, *C. N.*, caudate nucleus; *C*, crus; *P*, pons, *M*, medulla; *O*, olivary body. The tracts for face, arm, and leg gather in the capsule and pass together to the lower pons, where the face fibres cross to the opposite VII. nerve nucleus, while the others pass on to the lower medulla, where they partially decussate, to enter the lateral columns of the cord; the non-decussating fibres pass to the anterior median columns. The effect of a lesion situated at four points in the tract is shown on the left side of the figure. At 1, a cortical or subcortical lesion, causing monoplegia of left arm; at 2, capsular lesion, causing left hemiplegia, at 3, crus lesion, causing left hemiplegia and right third nerve palsy; at 4, pons lesion, causing alternating paralysis of right face (seventh nerve) and left arm and leg. (After M. Allen Starr.)

It is characteristic of paralysis due to lesion of the intracranial motor tracts (upper motor neurone) to take on the spastic type, and be followed by contractures of the affected limbs. The electrical reactions remain normal, the muscles do not atrophy, the deep reflexes are retained, indeed are often increased, and the extensor plantar response (Babinski) is usually present as the indication of pyramidal irritation.

LESIONS OF THE POST-CENTRAL CONVOLUTION.—The details of the anatomical course of the fibres which carry various forms of sensation—touch, temperature, and pain—cannot here be followed out. From the cord they run in the fillet by way of the formatio reticularis, and probably end, at least the majority of them, in the optic thalamus, which is a relay station; thence they pass through the posterior part of the internal capsule, up through the corona radiata, and end in the cortex, as already described, in or just behind the post-central convolution. Irritative lesions of this tract cause various disturbances of sensation such as numbness, tingling, and other paræsthesiæ, including hyperæsthesia. Lesions causing paralysis are evidenced by anæsthesia, complete or partial. There are all grades of interference in both directions. According to the position of the lesion in the cortex the primary centres for tactile sensation may be alone affected; or in addition to this the deeper and more posteriorly situated centres for pain, heat, and for the appreciation of muscular action (kinæsthesia) or the position of joints may be interfered with. The varying effects of a lesion according to its situation in the sensory tract are sufficiently indicated in Fig. 54.

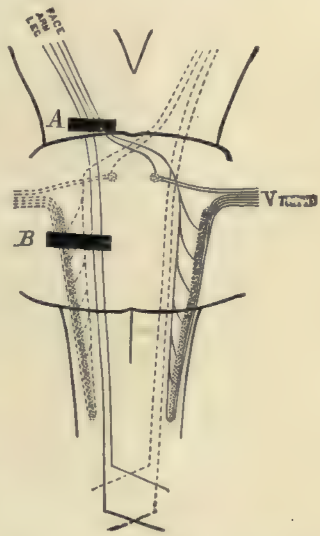

Fig. 54.—The Sensory Tract in the Crus, Pons, and Medulla, showing nucleus and roots of fifth nerve. At *A*, lesion in the crus, which is above the decussation of the fifth, causes right hemianæsthesia; at *B*, lesion in the pons, affecting the fifth of the same side, causes "crossed" or "alternating" hemi-anæsthesia, left face and right side of body. (From M. Allen Starr.)

If this interference with the incoming sensory impulses is extensive, it may cause a certain degree of motor paralysis, due simply to the fact that man is, like all animals, largely dependent for his so-called voluntary movements upon the integrity of reflex arcs. This condition was perfectly illustrated in a case reported by Cushing of a stab wound of the post-central convolution and the adjacent parietal lobe. The analogon is found in Sherrington's experiment of cutting all the posterior spinal roots of one side with resulting complete motor paralysis of the same side. Horsley has laid special emphasis upon the early and more minute alterations in disturbance of tactile sensation when of cortical origin, particularly upon loss of the power of localizing points of contact. In such cases when the dorsum of the hand, as being more sensitive than the palmar surface, is tested with cotton-wool, a topognostic error is frequently found which consists in this, that the patient locates the point of contact some distance proximal to its actual site. It is not infrequent for quite large lesions to produce but slight degrees of anæsthesia, and these have to be carefully sought for. The superficial reflexes are frequently lost on the side of the anæsthesia, the deep ones being preserved.

Lesions of the Parietal Lobe.—This lobe is made up of the superior and inferior parietal lobules separated by the interparietal fissure.

The Left Superior Parietal Lobule.—This is by common consent believed to be the seat of all those elaborated memory concepts concerning the character of objects, their form, density, weight, and general appearance, which together make up our stereognosis. They probably enter also, secondarily and somewhat indefinitely, into the general concept of impressions received from other special senses, such as hearing, taste, or smell. A destructive lesion in this lobule abolishes the power of recognizing objects by handling. Various cases have been reported of late years in which the loss of this sense was a very prominent symptom and sufficed in itself to determine the focal diagnosis.

The Left Inferior Parietal Lobule.—This lobule consists of the supramarginal gyrus which caps the posterior and upper end of the Sylvian fissure, with the angular gyrus or *pli courbe*, which winds round the posterior extremity of the first temporo-sphenoidal fissure. A lesion of the latter causes word-blindness, the patient cannot understand written language—he sees the words, but attaches no meaning to them; it is as if he were reading a foreign language. The same is true of letters and of numbers. On the right side the parietal lobe is a silent area, so much so that decompressing operations, even those which might ultimately lead to hernia cerebri, are not infrequently done at this point.

Lesions of the Occipital Lobe.—The cuneus and the lingual lobule on the mesial aspect form one end station of the general optic tract leading to the retina at the other end. The optic fibres leaving the retina, and passing along the optic nerve, undergo in the chiasm their well-known partial decussation, so that fibres of, say, the left halves of the retinæ unite in the chiasm, to form a single tract which ultimately pursues its course on the left side to the left occipital lobe. The central visual impulses from the macula lutea pass into both optic tracts. Each tract running backward winds around and below the crus on the outer side, and arrives at the first relay station, viz., the primary optic centres situated chiefly in the external geniculate body, also in the posterior part of the optic thalamus, and in the superior corpora quadrigemina. Here new fibres arise, forming the optic radiations of Gratiolet, which pass through the internal capsule at its hindmost part, circle round the external surface of the posterior horn of the ventricle, and reach the cortex in the cuneate lobe. Here is the centre of primary perception of visual impulses, those which take a place in consciousness.

The effect of lesions at various points along this tract is indicated in the accompanying illustration. (Fig. 55.)

The effects of lesions of the optic tract and radiations vary a great deal according to the situation of the lesion. (Fig. 55.) The tract as a whole, from retina to occipital lobe, is divided roughly into two parts by the relay stations of the corpora quadrigemina, optic thalamus, and external geniculate body—the primary optic centres. The chief distinction between lesions in front of and those posterior to this station is afforded by Wernicke's sign, which refers to the pupillary reaction in the halves of the retinæ affected. If the optic fibres are interrupted between retina and optic thalamus there is loss of the pupillary reflex when light is thrown on the blind half of either retina; whereas, if the interruption be situated posteriorly to this point, which signifies that the pupillary reflex arc is intact, the sign is not obtained. Other diagnostic considerations depend chiefly upon the fact that hardly any lesion can be so small as to affect the visual fibres alone. Pressure upon neighboring structures, therefore, yields associated symptoms which assist greatly in the diagnosis. In the first place, with a growth situated in the cuneate lobe there is a distinction to be drawn according to its relation to the calcarine fissure. It is believed that this fissure is the boundary line between the cortical representation of the upper and lower quadrants of the corresponding half of the visual field. Thus a lesion of the left cuneus, if limited to the portion above the calcarine fissure, causes blindness of the right lower quadrant of both visual fields, while if it lie below the fissure it causes blindness of the right upper quadrant of both fields. This condition represents one of the varieties of quadrantic hemianopsia. Ordinarily speaking, of course, the whole cuneate lobe, or at least its subcortical fibres, is involved (Fig. 55, *Cal* or *RO*) and such a lesion gives rise to blindness in the homolateral halves of both retinæ—bilateral homonymous hemianopsia. If the lesion, however—for example, a tumor—spread toward the cortex and anteriorly, it will soon involve the angular gyrus, and then there appears the associated symptom of word-blindness. In this situation the patient is usually not conscious of his half-blindness, which is first revealed by examination. The condition of word-blindness brings with it often some disturbance of the other parts of the speech apparatus. One may get word deafness and some degree of motor aphasia as well. Occasionally there are subjective symptoms consisting in hallucinations of sight.

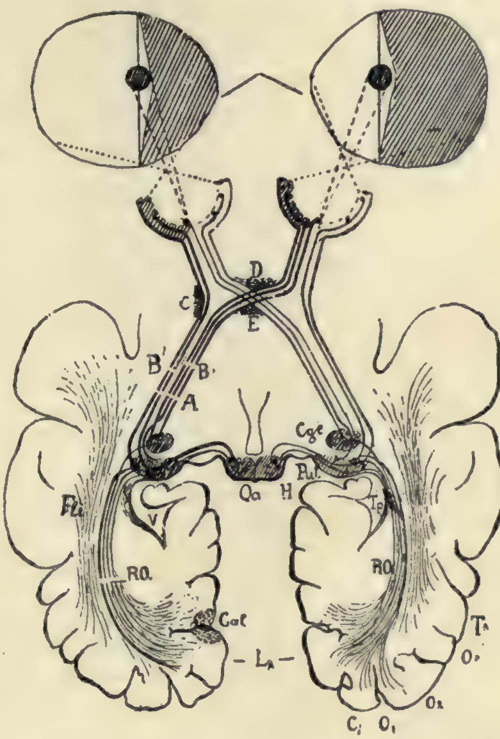

FIG. 55.—Varieties of Hemianopsia and their Anatomical Lesions. (Raymond, quoted by Duret.) *Cge*, External geniculate body; *Pul*, pulvinar, *Qa*, corpora quadrigemina; *H*, hippocampus; *Tp*, tapetum; *RO*, optic radiation, *Fli*, inferior longitudinal fasciculus, *Cal*, calcarine fissure, *Cu*, cuneus. Lesions.—At *Cal* and *RO*, cortical and subcortical, a lesion produces bilateral homonymous hemianopsia with normal pupil reaction. At *Cge* or *Pul* (primary optic centres), homonymous bilateral hemianopsia, with hemianopsic pupil reaction, that is, with loss of pupillary reflex in half of each eye. At *A*, hemianopsia of same nature as the last. At *B*, a temporal hemianopsia of the opposite eye. At *D* or *E*, bitemporal hemianopsia. At *B′* or *C*, a nasal hemianopsia of the same side.

If the lesion affect the optic thalamus, superior corpora quadrigemina, or external geniculate body (*Cge* or *Pul*, Fig. 55) the same bilateral homonymous hemianopsia is caused, with the addition of the Wernicke pupillary sign (loss of the reflex). The patients, however, are conscious of their infirmity; they see black in the affected halves of the retinæ. In the associated symptoms one notices a lack of aphasia; but, because of the likely coincidence of pressure on the posterior part of the internal capsule, there is frequently associated a hemianæsthesia, less often hemiplegia, and the interference with the optic thalamus is apt to result in choreic or athetotic movements. With the lesion farther forward in the optic tract (at *A*) there is the same bilateral hemianopsia, but the pressure on the crus around which the tract winds frequently results in hemiplegia and a palsy of the basal nerves, particularly the third, fourth, and sixth. A lesion situated in the angle of the chiasm, either anterior or posterior, is apt to cause bitemporal hemianopsia because of pressure principally on the centre fibres of the chiasm, which supply the nasal halves of the retinæ. Such a lesion usually consists in a tumor of the hypophysis.

Lesions of the Temporal Lobe.—On the right side the temporal lobe represents a silent area. The superior temporal convolution of the left side (speaking of right-handed people) harbors the centre for word-hearing in its posterior part. With this centre destroyed, the patient hears what is spoken to him as if he were being addressed in a foreign language. He hears the sounds, but they convey no meaning to him. Such a condition of word-deafness nearly always carries with it a serious concomitant effect upon the other centres of the speech mechanism by interference with association fibres. The writer has observed a very clear case of this sort as the result of a depressed fracture; though the depression was removed, re-education took place very slowly.

Anteriorly in this lobe is situated, according to Mills, the centre for the memory pictures of tones as distinguished from words. The uncinate gyrus situated at the tip of the lobe anteriorly on the inferior mesial surface seems to contain the cortical centres for taste and smell. As has been pointed out, this area in severe head injuries is apt to suffer some degree of contusion. In one instance, seen by the writer ten years ago, of bursting fracture of the middle fossa, which evidently tore across both optic nerves, there was found upon examination ten years later, besides complete blindness, a considerable degree of loss of taste and smell, perhaps referable to a coincident lesion of the uncinate gyrus at the time of the original accident. If such is the case, it goes to show that the cortical loss of taste and smell may be practically permanent. Another case seen by the writer (Royal Victoria Hospital, Dr. Bell's service) seemed to indicate a lesion affecting smell in this situation. The patient entered hospital for attacks of Jacksonian epilepsy which always began with an olfactory aura consisting in a disagreeable smell. An old depressed fracture was found from which a spicule of bone had been driven vertically inward for a distance of over an inch and was surrounded by a cyst involving the superior temporal convolution.

Lesions of the Frontal Lobe.—The frontal lobe, considered anatomically, occupies a very large area. It is divided into pre-frontal and post-frontal areas. The latter abuts on the anterior central convolution, which, though belonging anatomically to the frontal lobe, is clinically considered to belong rather to the Rolandic area. In the post-frontal lobe are situated centres for conjugate movements of head and eyes, the so-called writing centre, and inferiorly Broca's convolution, the seat of motor speech. (See Figs. 50 and 51.) Marie has within the last two years endeavored to overthrow this foundation stone in the doctrine of localization; and late reports (Souques) would seem to show that, to a certain extent at least, his beliefs are justified. For the present, however, we must continue to regard this portion of the third frontal convolution as containing the stored memories of spoken words.

The pre-frontal area is in all probability concerned with the processes of the higher intellectual life. At least the majority of present-day neurologists are of this opinion, although a few, notably Bruns, deny to it any particular faculty of this nature, and believe that the cortex as a whole is the organ of thought. Nevertheless, the observations in which interference with this lobe has been accompanied by marked loss of memory, and of the power of application or concentration, by changes in character, particularly in the direction of increased irritability, are so numerous that one can hardly avoid the conclusion that it has really to do chiefly with the association processes of thought.

Discussion chiefly surrounds, nowadays, the question as to whether the left pre-frontal area has alone to do with this function, or whether this is shared in by the right. The first is the more widely held belief. In the Royal Victoria Hospital records and in personal observation I find several instances which speak strongly enough for the generally held view.

In this connection the experiments of Franz in the line of ablation of the pre-frontal lobe or lobes in animals that had been taught definite association complexes (various tricks leading to the final getting of some tit-bit) are suggestive. Such an operation regularly destroyed for a time the memory of these tricks, although they could be relearned with ease, the more ingrained the habit was the more quickly was it regained.

The posterior portion of the frontal lobes possesses apparently some degree of control over motor phenomena. It is not infrequent to find in instances of destruction of the lobe symptoms of ataxia in the contra-lateral limbs, and the fact of this so-called frontal ataxia, or loss of co-ordination in movements, has frequently given rise to confusion with the similar effect of cerebellar lesions. Late experiments of Mingazzini and Polimanti seem to indicate that each frontal lobe has some influence on the co-ordination of the movements of the contralateral limbs, and particularly of the anterior limb. Illustrations of this fact will be mentioned in the section on Tumors.

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XVIII. THE CEREBELLUM.

Although the physiology of the cerebellum is a field in which there is yet much digging to be done, we have, by the labors of Luciani, Thomas, Russell, Clarke and Horsley, van Gehuchten, and many others, gained a sure knowledge of a certain number of facts of far-reaching importance, sufficient to render the symptomatology of cerebellar lesions comprehensible and their diagnosis moderately certain.

The cerebellum consists really of two organs, the cortex and the intrinsic nuclei: the latter consist of the dentate, the tegmental, and the paracerebellar or bulbar nuclei; the cortex is divisible into that of the hemispheres and that of the middle lobe or vermis. Of the vermis we know that it is the oldest in the process of evolution, and that its development in size goes more or less parallel with the necessities of equilibrium. The hemispheres are of later development, and appear only in birds and mammals; their development seems to go hand-in-hand with that of the cerebrum and the pons. The cerebellum has very numerous and wide connections with the rest of the nervous system. To the middle lobe come directly fibres from the spinal cord and from the labyrinth, probably through Deiters' nucleus. The former possibly carry the sensations of the position of joints and the tension of muscles, the latter bring impulses directly concerned with the maintenance of one's centre of gravity, impulses which are peculiar to the semicircular canals. It is evident, therefore, that the vermis has a very great deal to do with the maintenance of equilibrium, and this prime fact has been known ever since Flourens nearly one hundred years ago removed the cerebellum in pigeons and saw them unable to stand or fly. Yet that the hemispheres have also to do with the maintaining of equilibrium is certain, as we know from clinical investigations. A lesion confined to the lateral cortex will still cause ataxia. However, the physiological value of the cortex of the hemispheres is much less known than that of the vermis. It seems to be established (Edinger) that the hemispheres receive afferent fibres exclusively from the cerebrum, not from the cord. The cortex of the cerebellum has no motor function analogous with that of the Rolandic area in the cerebrum;

it is altogether receptive in nature, and receives only afferent axones. Its efferent axones are association fibres which connect it with the intrinsic nuclei (dentate and roof). These represent, as said, a second organ, which elaborates impulses and sends out efferent axones to the ganglionic cells of the cerebral, medullary, and spinal nuclei.

The late work of Clarke and Horsley has shown that whatever rôle these intrinsic nuclei play in preserving equilibrium, a matter concerning which we are somewhat in the dark, they at any rate possess some influence of a motor character ~~over the general~~ skeletal muscles. The very ingenious and accurate experiments of these workers in the way of galvanic stimulation and electrolytic destruction of minutely localized areas of the cerebellum, made possible by the device of an apparatus carrying an insulated needle which is fixed immovably to the animal's skull, showed that the motor influence which the intrinsic nuclei exercise was of the nature of tonus and hypertonus, and that, in particular, "the essential motor representation of the parts of the body in the intrinsic and paracerebellar nuclei are in the former the movements of the eyes and head, and in the latter more especially those of the trunk and limbs."

The conception then is that these nuclei, on the basis of information sent them by the cerebellar cortex, elaborate automatically and subconsciously motor impulses which serve to maintain general muscle tone, and which presumably have also to do obscurely with the co-ordination of those muscles which in particular have to do with the maintenance of one's equilibrium and with progression, especially those of the trunk and lower limbs. In this sense the cerebellum, as Bruns expresses it, stands at the top of a reflex arc, afferent impulses coming in from the spinal cord and the semicircular canals to the cortex, passing thence to the intrinsic nuclei, and then proceeding as efferent motor impulses to the skeletal muscles, including those of the eye. This reflex arc concerns chiefly the cortex of the vermis. There remains the cortex of the lateral hemispheres. That these have a great deal to do with the matter is indubitable, for their increase in size goes parallel with the evolutionary development of the cerebral hemispheres, particularly of the motor and frontal districts, as one rises in the animal scale. They receive afferent axones exclusively from the cerebrum through the pons, and send out efferent axones to the intrinsic nuclei also. In this sense there apparently exists a second and higher reflex arc of which the cortex of the cerebellar hemispheres is the turning point. Its physiological value and its place in clinical lesions are yet unclear.

When these lines of communication are broken, as for instance through destruction of the semicircular canals, or of the vestibular nerve in its course, or of the central junction of the cerebellum, or even of certain parts of the frontal lobe as yet not certainly known, there must develop a lack either of the sensory or of the motor portion of the arc or arcs, a lack either of information given or of the power to use that information. In either case ataxia, inco-ordination, must result, and we thus see that the prime symptom of cerebellar lesions is ataxia or inco-ordination.

There resides, however, in the cerebellum that second property of supplying tone to the skeletal muscles. As Clarke and Horsley with their insulated needle approached the intrinsic nuclei of the cerebellum, a minimal stimulus was found to grow maximal and to end in the provoking of a convulsion the nature of which was tonic, as opposed to the clonic character of the cerebral fit. It was characterized in the main by tonic extension of the trunk and leg joints, with flexion, often unilateral, of the arms, and with tonic conjugate deviation of the eyes to the side of the lesion; sometimes, however, a skew deviation appeared, the eye on the side of the lesion being usually turned inward and downward, the other upward and outward. A very analogous type of convulsion in the human being was described many years ago by Hughlings-Jackson, who recognized the attacks as "cerebellar fits." Stewart and Holmes have also seen not infrequently the skew deviation in lesions of the cerebellum, especially following operation. These phenomena are clear evidence of Hughlings-Jackson's original contention, that the contribution of the cerebellum to the general nervous mechanism—or, as he called it, "the cerebellar influx"—was one of *tone*. Bouché, working under Horsley on the details of the epileptic convulsion as caused by absinthe, found that the clonic convulsion of cerebral origin was immediately converted into a tonic one upon section of the brain stem during a fit, thus leaving in action only the cerebellar influences; and Sherrington's "decerebrate rigidity," meaning a general hypertonic muscular condition following the removal of the cerebral hemispheres, is fair evidence in the same direction. The stimulation of these nuclei sometimes also causes forced movements of rotation, an observation that was made very early in cerebellar physiology.

To summarize, therefore, it would seem that the cerebellum possesses two chief functions: that of automatically co-ordinating muscular action, of which the maintenance of equilibrium is but one part, and that of giving tone to the skeletal muscles generally. The one is clearly complementary to the other. Clinically, destructive lesions of the cerebellum cause, therefore, a loss of equilibrium, ataxia, and a loss of tone. These are the every-day results. In addition, there are occasionally observed the signs of stimulation, by tumor, hemorrhage, abscess, etc., of the dentate and roof nuclei in the way of Jacksonian "cerebellar fits." So far these have been but rarely observed. Some authors have described also, as another effect of cerebellar lesion, an actual paresis of the homolateral muscles. This is denied by others; and it is possible that it may be no more than loss of tone.

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XIX. THE LATE EFFECTS OF CRANIAL INJURIES.

It may be premised that any cranial trauma, whether light or severe, may be followed, even after apparent complete cure, by late effects of greater or less severity. It has been found, after the cases of pure traumatic hysteria and neurasthenia have been excluded, that, in the majority of instances in which these various late effects appear, there are present very definite anatomical lesions. In the scalp there may be a tender scar; or, where a defect in the bone exists, the scalp may be fused with the meninges or even with the cortex in one large plaque. In the cranium the most frequent lesion found is that of osteosclerosis. The thickening may attain three times that of the normal, and Horsley in partic-

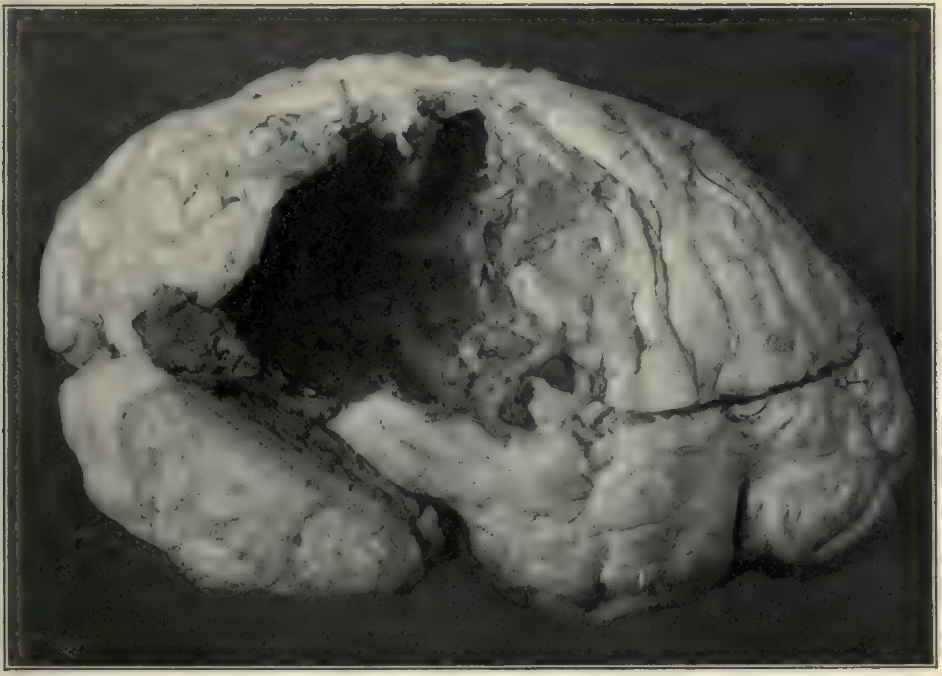

Fig. 56.—Brain in Case of Traumatic Porencephaly, the Opening Extending from Outside the Skull to Lateral Ventricle. (Dr. Shirres' and Dr. Armstrong's case, Montreal General Hospital.)

ular has called attention to the fact that it may be the sole cause of persistent headache, which is relieved by the removal of the thickened bone. Where a defect exists in the skull the violence has usually been severe, and the fibrous bridge uniting external with internal coverings fills the gap; it is not likely that the mere fact of the defect has of itself any influence in the causation of symptoms. The wounding of the meninges or cortex by splinters from depressed fractures is frequently found. In Tixier's statistics such splinters were present in one-third of the cases. There may be externally not the least evidence of such a condition.

Another lesion rarely found is that of the unabsorbed extradural blood-clot. This may remain hemorrhagic for many months, even years, yet more often becomes a serous cyst between the dura and the bone. Broca quotes Legouest, who found a doughy mass of extradural clot still unorganized after three years. The lesions of the meninges themselves are multiform. The dura may be pinched between the edges of a fissure, but in the great majority of cases the trouble lies in the adhesions that form between the dura, pia-arachnoid, and cortex as a result of old-standing hemorrhages. In this way both membranes may be fused

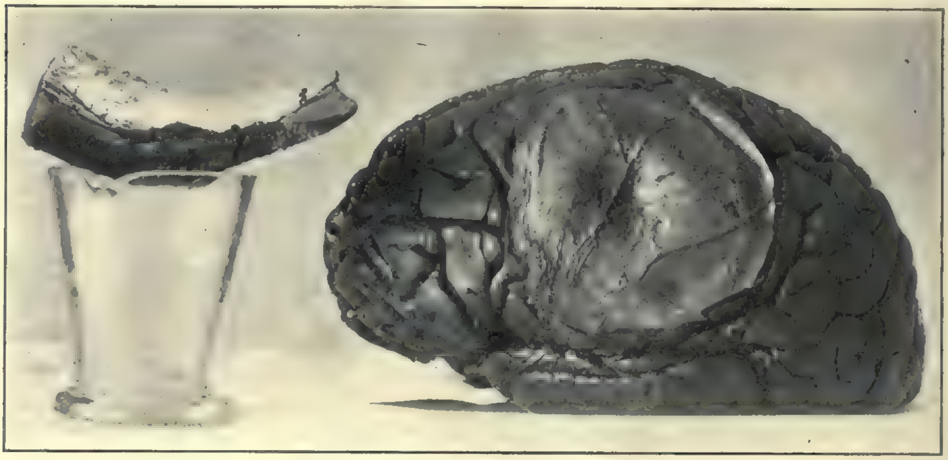

Fig. 57.—Endothelioma of the Dura Mater, apparently taking origin at a point where an exostosis of the internal table caused irritation. Note the depression in the dura mater and cortex. The exostosis was small, rough, and porous and is better seen in Fig. 58. It was situated over the left Rolandic region. The tumor underlies it directly, and could be shelled out at post-mortem examination with ease; it had done no more than compress the cortex. Illness had lasted one year; the chief symptoms were motor aphasia, paresis of right arm, slight weakness of the leg and face too; numbness in right hand and arm; and some mental disturbance. (Path. Dept., Royal Victoria Hospital, 17, 1902.)

together into a thick plaque, which at times encloses in its meshes a considerable quantity of serous fluid. The latter sometimes increases in amount, becomes a predominating feature, and there is ultimately found a multilocular serous cyst in the pia-arachnoid.

The lesions in the brain are also numerous. Tixier divides them into those which are visible on the surface, those which are subcortical, and, finally, those which can be recognized only by microscopical examination. Those visible when the cortex is laid bare consist in the late changes involved in patches of encephalitis and hemorrhage. According to the lapse of time the pigment is more or less reabsorbed. Thus one finds yellowish spots in the brain substance representing old punctate hemorrhages; patches of softening are seen in areas of discolored cortical tissue which is sometimes indurated and usually depressed below the surface. These indicate old foci of contusion with aseptic encephalitis. Or, again, the original hemorrhage combined with softening may have destroyed the brain to a considerable extent, so that, as in Chipault's case, there may be found under a sclerosed arachnoid a multilocular condition filled with serous fluid and extending to quite a depth in the cerebral substance. Here the brain area involved looks as if it had undergone polycystic degeneration and was converted into cavernous tissue. Or, again, whether from injury or encephalitis, a single cyst, small or large, may be the end-result. Not infrequently such porencephalic cysts communicate with the ventricles. In the illustration here reproduced (Fig. 56) there was found at operation an immense cavity which opened widely and directly into the lateral ventricle. At the age of sixteen, the patient being twenty-six years old at his admission to hospital, a tree had fallen on his head. The left side of his body remained paralyzed for several months, but he ultimately recovered full power, and worked as a locomotive engineer without interruption. Three years after the accident, some doctor incised a fluctuating swelling which had appeared on the head over the site of the injury (traumatic spurious encephalocele), under the idea that is was a cyst of the soft parts. This healed over. Ultimately he developed Jacksonian fits, for which he came to hospital. At operation, after exposing the region, one came immediately through a gap in the bone and dura down into the open lateral ventricle. Death occurred later from meningitis.

One of the late effects—a rare one, it is true—is the development of a tumor directly underneath the point of cranial injury. In Bennett's case the connection of cause and effect seems clear. One year after a blow on the head, operation revealed a glioma directly under the site of the injury. I reproduce here two similar cases belonging to the pathological department of the Royal Victoria Hospital, in which it would appear that endothelioma had developed from a localized exostosis of the inner table of the skull at the site, in one of them at least, of an old injury. (See Figs. 57, 58, 59, and 60.)

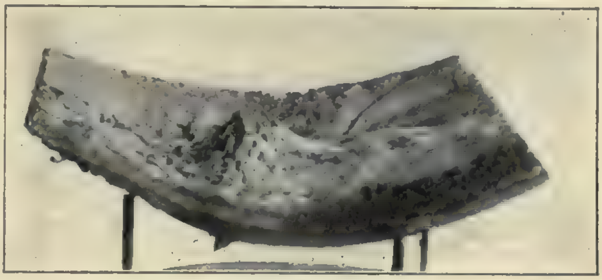

FIG. 58.—Section of Bone of Specimen Illustrated in Fig. 57, Showing Exostosis Mentioned from Another Point of View. (From the Pathological Dept. of the Royal Victoria Hospital, No. 17, 1902.)

Those lesions which are subcortical consist altogether in cysts or abscesses, and the former may be considered to represent the ultimate result in many cases of intracerebral hemorrhage. A foreign body is present in some cases, either in the form of a bullet or in that of spicules from depressed fractures; and such things the brain often tolerates for a long time before rebelling.

Finally, there is a definite class in which minute lesions alone are present and are recognized only by microscopical examination. Undoubtedly they are frequent and important. They consist chiefly in reparative gliosis of the cortex, accompanied by degeneration of the cortical ganglionic cells. Their existence has been firmly established by various observers and may be accepted as representing a direct effect of injury. Koeppen especially demonstrated their existence underneath a localized subdural hemorrhagic cyst; and it is frequently observed that the reparative gliosis and the degeneration of cells exceed in intensity and extent the degree of the hemorrhage; even the fact of hemorrhage sometimes is unnecessary, for nerve fibres may degenerate as the result of a sort of microscopical contusion, as has been indicated in the section on Concussion. There is clinical evidence also that such lesions are possibly causal of symptoms; at least sections of the cortex, excised by Horsley's method in cases of traumatic epilepsy, which appeared to the naked eye perfectly sound, have been shown microscopically to be in a condition of advanced degeneration of cells, with glial overgrowth.

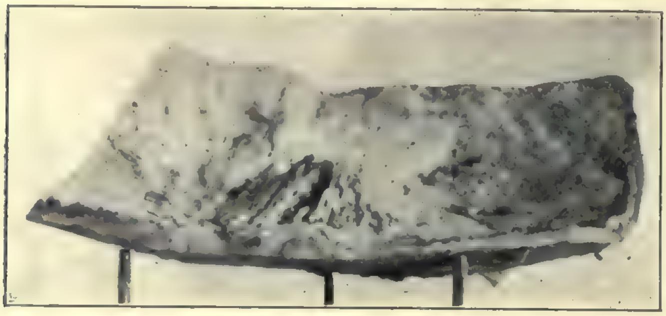

FIG. 59.—A Section of the Calvarium from Another Case of Dural Endothelioma, Showing a Similar but Larger Exostosis, which measured 2½ cm. (1 in.) long and wide, and 1 cm. (⅜ in.) deep. The tumor arising in the dura covering this exostosis (endothelioma) is illustrated in Fig. 60. The exostosis was situated about at the eminence of the right parietal bone. (From the Path. Dept. of the Royal Victoria Hospital, 45, 1901.)

Besides these gross and minute changes in cellular structure, it would seem that hypertension of the cerebro-spinal fluid, either in the ventricles or in the cortical subarachnoid spaces, may be in some obscure way chronic, and cause such symptoms as headache, vertigo, even epilepsy. Tixier found that in twenty per cent of his cases an abnormal amount of fluid was noted. And on the clinical side there have been reported a number of instances in which lumbar puncture has effectually cured such symptoms.

These are the various pathological lesions which may remain as the result of head injuries. The clinical phenomena are perhaps not less various. They consist in all sorts of mental and physical disturbances referable to the cerebrum, from slight and transitory feelings of malaise up to general epilepsy, and even beyond that into the domain of actual insanity. Thus one finds neuralgias, migraine, headache, dizziness, attacks of petit mal, Jacksonian fits, and generalized convulsions. The most frequent consist in headache and vertigo.

On the mental side there may develop change in character, usually in the direction of increased irritability, loss of memory, which is not alone the retrograde amnesia of Gussenbauer relating to the events immediately preceding the accident, but also concerns the power of learning afresh by rote; loss of power of concentration, of keeping one's attention fixed; loss of energy in a general way, disinclination to work, interference with the various reasoning processes that are necessary to the conduct of business; and so on. The picture forms often a characteristic whole, to which Pearce Bailey has given the name of traumatic cerebrasthenia. He, with Spiller and Cushing, has emphasized the close connection of such conditions with traumatism of the skull,

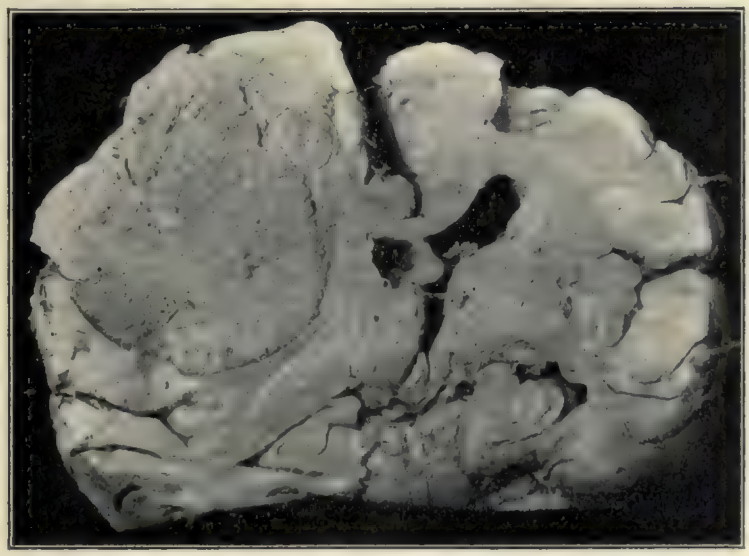

FIG. 60.—Right Parietal Endothelioma Growing from the Dura Mater at a Point at which the Pressure of an Exostosis of the inner table (see Fig. 59) caused chronic irritation. The tumor measured 6x6x5¾ cm. (2⅜ in. x 2⅓ in. x 2⅓ in.), and occupied the greater part of the right ascending parietal convolution It extended 3 cm. (1 in.) into the frontal lobe beneath the surface. Symptoms had begun five and a half years previously, evidencing very slow growth of the tumor. For three years they consisted in Jacksonian attacks with twitching of the left face at times, but frequently quite atypical, rather generalized. Six months before death, headache, vomiting, failure of sight, paresis and numbness of left hand and arm, deviation of tongue to left, and nystagmus came on and progressed rapidly, ending in sudden death. Note lateral dislocation of the falx and ventricles; also the encapsulation of the growth. (Path. Dept., Royal Victoria Hospital, 45, 1901.)

particularly the likelihood of their developing as the result of the organization of subdural clots with formation of adhesions. The histological examination of the cortex under such subdural hemorrhages, if they last any time (Koeppen), reveals a possible pathological basis for the neurosis in the shape of degeneration of pyramidal cells and gliosis consequent upon the pressure. Hence Cushing's proposal to remove the subdural blood which is usually present in moderately severe, even if not dangerous, cases of traumatic compression, gains an added justification; it is certainly probable that the post-traumatic neuroses would be greatly lessened by such a procedure. Of all these lesions, however, the most important are undoubtedly the partial and general epilepsies that may develop. This question will be separately discussed

The length of time which elapses between the injuries and the appearance of these late effects varies greatly. It may be a few weeks or months, but sometimes it is years, and the same variability is seen in the course pursued by these cases. Remissions and recrudescences are common; or the trouble may remain stationary.

These modalities having been enumerated, it only remains to discuss briefly their comparative frequency, their prognosis and treatment. It may be said, in general, that some of these late effects are apt to persist for many years, or even permanently, in a large proportion of cases, variously estimated at from ten to thirty per cent. (Bruns, Bullard, English, Brewitt, Bailey.) A mere headache is very frequent. It is occasionally diffuse, but is often confined to the area occupied by a scar, and this is tender on pressure. Its degree of severity is sometimes so great as to prevent work; and it is characterized clinically by being very rebellious to treatment. Operation for the headache alone is justified, if it seems to be localized in a tender scar in the scalp, or if there be suspicion of a localized thickening of bone. But if the headache be diffuse and unassociated with other localizing signs it is quite unjustifiable to interfere. Medical treatment should be first given a trial, and in this may be included lumbar puncture, which, according to the French authorities, is frequently very efficacious.

Troubles of the intellect and of mentality amounting to idiocy or insanity of severe grade are rare in adults. There are three clinical forms: general paresis, traumatic dementia, and general epilepsy with mental disturbances. Whether the first of these is really ever due to injury is contested by some. All such cases go to the asylum, and need not be fully considered here. The old case of Prescott Hewitt concerning a boy who, following a blow on the head, developed an arachnoid hæmatocele in the frontal region, which led to insanity, yet remained unsuspected till his death after he had been insane for a number of years, is also instructive. Short of this one finds symptoms sometimes associated with various signs of localization. Thus the loss of memory, state of depression, and occasionally delirium are often found together with epileptoid crises and diverse kinds of paralysis. Such always represent definite lesions of the cerebral substance. Occasionally there are motor paralyses unassociated with epileptic fits, and these may be very difficult to differentiate from the symptoms of traumatic hysteria. Their cause lies in such lesions as hyperostosis, hemorrhagic cysts, and local softenings of the cerebral cortex from contusion.

Sensory paralyses are also found, occasionally astereognosis; these, however, also depend upon the organic lesions which have just been mentioned. There may also be more or less pronounced interference with the work of the special senses; ocular troubles, in the way of hemianopsia from cortical injury, are not infrequent, but the lesser degrees affecting the perception of colors are also found. An occipital cortical lesion may give a visual aura if epilepsy develops.

As to treatment, the indications for operation must in the main be based upon the diagnosis of remediable organic lesions, a diagnosis which implies the presence of clear focal signs, but which can rarely be sure of pathological accuracy. The operation is therefore to some extent exploratory; it will consist in the removal of sclerosed or depressed bone, of meningeal adhesions, of cortical or subcortical cysts, or will otherwise meet the pathological indications as above set forth. Here it may be remarked that contractures do not form a contraindication; they may be due to simple pressure on pyramidal fibres and not to actual degeneration, and may therefore disappear if pressure is relieved. Even intellectual failure, if associated with other definite signs, is not a contraindication; it may improve if the original cause is removed. Hedges' case is instructive in this respect, as is also Hollaender's.

Fig. 61.—Chipault's Case of Traumatic Porencephaly with almost Complete Destruction of the Left Rolandic Area, one year after decompressive craniectomy with liberation of adhesions between dura and cerebral substance. The child, previously quite invalided by spastic hemicontractures (right) and frequent epileptic fits, was able to walk and talk; and later developed quite normally. (Chipault, "État Actuel de la Chirurgie Nerveuse," vol. i., p. 178.)

In general, as Chipault points out, the infant's brain bears immediate damage very well and late damage very ill. The child recovers; its life is not jeopardized; but it grows up an idiot. Operation therefore should be undertaken before the child comes to such a pass. Chipault's operation, releasing adhesions in a case of traumatic porencephaly (Fig. 61), was followed by a remarkable result, spastic contractures and epileptic fits being cured, and the child's mind developing normally. Much may be done where there is an organic lesion to be removed.

For the cases of post-traumatic neurosis, as well as the many minor troubles of headache, giddiness, susceptibility to alcohol and tobacco, mental confusion, and so on, there is no doubt but that the prophylaxis of prolonged and absolute rest following the accident is of prime importance. English has laid just emphasis on this point. The patients are sent out of hospital too soon, and resume work too soon. If possible, two or three months should be devoted to recovery even in ordinary cases of concussion.

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XX. EPILEPSY.

Classification.—For many years two main types of epilepsy have been recognized—the genuine, essential, or idiopathic form, and the partial, focal, or Jacksonian. The usual distinction between the two lies partly in the presumed cause, partly in the symptoms. It is generally assumed that in Jacksonian epilepsy there exists some organic focus of cerebral irritation, while in the idiopathic form such a focus does not exist or at least cannot be demonstrated. In the symptoms of the partial form the convulsion begins in any one muscle or group of muscles, spreads from this point with a definite march to other groups, and may go on ultimately to involve the musculature of the whole body. With this, consciousness is frequently not lost save when the convulsion becomes general. In the idiopathic form the fit begins always with sudden loss of consciousness, frequently with a cry, and the muscles of the body as a whole are first involved in a tonic convulsion, which shortly gives place to clonic spasms. These are the generally recognized gross differences. There are those who recognize only one epilepsy, the essential form, and consider all convulsions from recognizable organic causes as being epileptoid, not true epilepsy. There are others, like Allen Starr, who believe that there is an underlying organic cause in all forms of epilepsy, even in the essential. The advance of our knowledge seems to justify more and more the latter view. It is impossible to keep the two forms absolutely apart. The epilepsy due to a focal irritation is sometimes found to simulate the essential type of convulsion; and, on the other hand, the idiopathic form—that is, those cases in which at post-mortem examination no lesion can be found—is sometimes observed to cause convulsions of the Jacksonian type. The one merges into the other. Yet while this tendency to unification is justified in a general way, the two forms, from the surgical standpoint, must be kept more or less separate. After all, the separation, in point of pathological findings, is more definite and better maintained than that which concerns mere symptomatology, and is also the surer foundation for reasoning. From experience we know that an organic lesion is present in the majority of Jacksonian epilepsies, and is absent in most of those of the genuine form. Therefore, *a priori*, surgery will have much to do with the former, little to do with the latter.

Pathology of Jacksonian Epilepsy.*—The evidence of operations and of post-mortem examinations shows that the organic lesion which acts as the starting-point of the fit in these cases may be one of many. There are two main classes, according as the lesion is situated in the brain or in the peripheral sensory field.

a. Changes in the Brain.—The most frequent cause is probably trauma, including those injuries which occur at birth, the effect of which is to produce at the time of their infliction, meningeal hemorrhages and cortical lacerations, sometimes a depressed fracture, or a spicule of bone penetrating the brain, or a hyperostosis; sometimes also a thickening of the dura mater, or a nipping of the dura in a bone fissure. All these result variously in cysts, foci of softening, meningeal adhesions, scars, and particularly the scars of cerebral tissue which consist in an overproduction of the glia fibres, the so-called gliosis. While these lesions are usually situated in or upon the cortex and the leptomeninges, they may also be found within the cerebral substance. A second great group represents the result of infections, which give rise to patches of encephalitis, particularly in infants and children. Such a condition may be primary, like the analogous anterior poliomyelitis; or it may complicate any one of the various fevers; and the affected brain substance may, according to the degree of softening undergone, repair itself either through gliosis or through cyst formation. Freud and Marie attach a great deal of importance to this cause. The infection of meningitis, if overcome, is apt to leave adhesions which may apparently cause fits in the sequel. The third great group is formed by those lesions —such as tumors, hydrocephalus, or abscess—which cause a diminution of the intracranial space. Fourthly, there is the toxic group, in which the poisons of uræmia, diabetes, carcinomatosis, alcohol, absinthe, and others, are sufficient to cause the development of convulsions. And there is finally another group in which, though the epilepsy is typically Jacksonian in character, there can be found at operation or at post-mortem examination no visible lesion whatever. In some of these cases microscopic examination reveals nothing, while in others it shows a degeneration of pyramidal cells and gliosis.

b. Disturbances in the Peripheral Sensory Field.—These disturbances consist ordinarily in painful scars, sometimes in such disorders as eye-strain, dentition, various genital affections, and others too numerous to mention. In these cases, the condition is given the more particular name of reflex epilepsy.

Pathology of Essential Epilepsy.†—The pathological anatomy of the idiopathic form has been very widely investigated, and it is generally believed at the present day that the various changes which are found in the cortex,

* Adolf Meyer. "The Pathology of Epilepsy." Med. News, July 18th, 1903; Amer. Jour. of Insanity, vol. lx., 1904, p. 673.

† Bouché: "La Pathologie de l'Épilepsie dite essentielle," Bruxelles, 1907.—Koeppen, in Archiv f. Psych., Bd. xxxiii., 1900, p. 568.—Turner in Journal of Mental Science, Jan., 1907.

changes consisting in degenerations of the ganglionic cells and overgrowth of the glial supporting tissue, represent the result of the disease rather than its cause. Whether the pathologists, however, do not go too far in denying all etiological importance to the histological changes which they find so regularly in the cortex is a question. It must be remembered that Koeppen has found very similar lesions as the direct result of trauma, particularly underlying intradural hæmatomata; and, generally speaking, they are found frequently in the cases which more or less clearly owe their origin to cerebral trauma, even in those of concussion alone.

TREATMENT.—What, in the face of these manifold differences in pathological findings, is the place of surgery?

Reflex epilepsy may be dismissed in a few words. The causal connection between a painful scar and epileptiform convulsions is perfectly established. That between such conditions as eye-strain, uterine and ovarian disorders and epileptiform convulsions is less certain; here the element of hysteria often comes in. In infants, whose cerebral cortex is notably unstable, it is probable that such peripheral irritations as an inflamed prepuce or the cutting of teeth may induce true reflex epilepsy.

In all these the suitable peripheral operation may justifiably be considered, and is frequently successful, if the epileptic habit be not ingrained. It is particularly likely to succeed in cases in which epileptogenic zones can be discovered, that is, where pressure on a painful scar suffices to provoke an epileptic attack.

We may at this point exclude from consideration that class which is dependent on space diminution, the tumors, abscesses, hydrocephalus, and others, inasmuch as the epilepsy is a mere incident of their being, and may be expected to disappear with their removal.

There remain for consideration the two groups of organic epilepsy (caused by inflammation and by trauma) and of idiopathic epilepsy. In all of these the one general principle obtains, in establishing indications for operation, that those symptoms must be postulated which give a reasonably clear index of a removable organic lesion. In other words, the type of "fit" must, on the one hand, be definitely Jacksonian in character; or, on the other hand, if it be generalized, there must be either in the history or in the physical examination of the patient some organic lesion which points the way to a site of intervention. In the former it is necessary that the fit should begin with the same symptoms, particularly the same aura or signal symptoms, should pursue the same march, and should leave paretic the same muscles in all attacks; this is our only guarantee (and it is hardly a guarantee) of a constant organic lesion. As regards the latter, the diagnostic indications are discussed farther on under Idiopathic Epilepsy.

Traumatic Epilepsy.—When one tries to estimate the results of operation for traumatic epilepsy one finds the effort beset with difficulties. The great majority of the cases have been reported much too soon. Often, as von Bergmann remarks, the report is published before the wound is healed. On the other hand, we know that any psychical disturbance—and an operation may be reckoned as such—is frequently followed by temporary cessation of fits. Then there come in those considerations which have to do with the patient himself, particularly the length of time during which the disease has already lasted, the great variety of lesions possible, and the extent of hereditary influence in the way of mental disease, lues, and alcohol. Further, there must be mentioned the difference in the technique of the various operators. One removes bone permanently, the other replaces it; one does not open the dura, another does; and of those who open it, the one closes it again, while the other cuts it out. It is easily seen that statistics based upon such variable factors as these give us very little help when we have to tell the patient what the outlook is with operation. With these reservations one may quote some of the figures.

Matthiolius collected statistics of 258 cases described in the literature of operations for Jacksonian epilepsy. Of these he says that 20 per cent were cured, that is, about 52 cases, but of these 52 cases only 10 were observed longer than three years and only 18 were observed for one year; 15 per cent of the total were improved, and 56 per cent remained unimproved; while 13 per cent died. More or less similar results have been obtained in smaller statistics. Thus Graf's statistics* concerned purely traumatic cases of Jacksonian epilepsy, and only those which developed late after injury. There were 146 cases; in 71 of these the cortex was exposed but left untouched; in 75 some operation was done on the brain in addition. In the 146 operations there was a mortality of 6 per cent; and the cures lasting over one year amounted to 7.6 per cent. It is thus evident that the results of operation, even for the removal of tangible lesions such as may be expected to have caused the disease, are on the whole poor.

There remains the subgroup in which the evidence of trauma as the causative factor is clear enough, but in which at operation no microscopical lesion is found. For these, Horsley proposed over twenty years ago that the cortical centre corresponding to that group of muscles in which the fits in the particular instance always began should be determined by faradism, and that this centre should thereupon be excised down to the white matter. It matters little whether one consider the cortex as the place of origin from which the motor discharge starts, or as merely an important relay station in a reflex arc; in either case the excision of the ganglionic cells would break the chain. This procedure has been carried out in a considerable number of cases where a definite organic lesion at operation was not visible in the cortex. Braun (*Deut. Zeit. f. Chir.*, Bd. 48) collected 30 cases; in 8 there was no result, 9 were improved, and 13 were cured; but of these 13 only 3 had been observed over three years. Rasumowsky ("Trepanation bei corticaler Epilepsie," *Arch. für klin. Chir.*, Bd.

*Graf, in Archiv f. klin. Chir., 1898, p. 391.

67) reports 7 cases of his own observed over three years; 2 were cured, 1 was greatly improved, 2 were doubtful, and 2 remained without change.

The recent figures of Cushing* and of Allen Starr † are, in a general way, of importance; yet, so various, in this series, are both causes and operations that, as has already been said, judgment in any given case as to the outlook of operation is almost impossible. Cushing notes that, when the fits are dependent upon porencephalic cysts, operation is useless. Starr's experience, which is especially valuable in that it now extends over a considerable number of years, practically agrees with that of Cushing. Both report about twenty per cent of three-year cures, and a larger proportion of marked improvements in selected cases.

Traumatic Cases with Generalized Convulsions.

Here, although a very definite history of injury is present, and although in most cases there is clear evidence in the scalp or cranium of a severe injury, plainly the cause of the epilepsy, the character of the fit is practically identical with that of genuine epilepsy, except that there is present an aura of definite character suggestive of a localized cortical irritation. It is not a frequent occurrence for this aura to be motor in character. Such cases generally show the typical Jacksonian fit. The aura is rather characteristic of an irritation in some other part of the cortex. Thus, it may be visual, the patient seeing lights or colors; it may be gustatory or olfactory, the fit beginning with the perception of foul odors or tastes (as observed by the writer in one traumatic case involving the temporo-sphenoidal lobe); it may be sensory, the patient feeling a numbness, tingling, or actual pain in some part of his extremities or trunk; it may be aphasic, and the loss of speech may be either on the sensory or on the motor side; it may be psychic, with perversion of ideas and with automatic acts; or it may suggest a cerebellar origin, with vertigo combined with extensor spasms referable to the action of the cerebellar nuclei. In all these cases the evidence points to one or other of the cortical centres, the function of which has been previously described. It is rather characteristic, when the aura or "signal" symptom is situated in one of these areas outside the motor region, for the epileptic attack to involve the entire motor cortex rather than any one part of it and to give rise to a generalized convulsion.

There has been much discussion as to whether operation is justified in these cases. Opinion on the neurological side is on the whole in favor of abstention; while with neurological surgeons it is rather in favor of operation. If operation be undertaken it should expose the cortex over the area indicated by the aura. If, when it is exposed, there is visible no gross lesion, opinions are again divided

* Harvey Cushing, in Keen's "Surgery," vol. iii.

† M. Allen Starr, in Trans. of the Amer. Med. Association, 1906, Section on Neurology and Psychiatry.

as to whether one should, following Horsley, excise the area of cortex in which it is believed the fit originates, or should close the wound without doing anything; and, further, as to whether one should remove the overlying bone for decompressive purposes and cut away the dura mater, or replace both. On all these questions we have as yet but little light. It seems, however, certain, as regards Horsley's excision of the cortex and Kocher's removal of bone and dura, that both give somewhat definite results; following both there is observed a certain percentage of three-year cures—a low percentage it is true, yet still quite definite and constant. Any attempt at comparison with the results obtained under the best conditions by medical treatment—for instance, those of the colony system, as carried out at Sonyea by Spratling*—is really not possible.

Non-traumatic Epilepsy.

This class consists of those cases in which the convulsion is due to some one of those causes already indicated (p. 293) as resulting from infection in brain or meninges, or from spontaneous vascular changes. The lesions are chiefly cysts, gliosis, or adhesions. The attacks may be Jacksonian or generalized. The exact diagnosis is not often to be made; but operation may be undertaken under the general principles already laid down. In the section on Cerebrospinal Meningitis, reference was made to a case of Cushing's in which the loosening of old meningeal adhesions was successful. Krause † has also had a fair measure of success in this class of cases; and he insists upon the advisability of the Horsley excision of the cortex where the latter is not grossly affected.

Idiopathic Epilepsy.

That a very few cases of genuine epilepsy are caused by a removable organic cerebral lesion is not to be denied. What concerns us is, first, how to pick out such cases; secondly, the question as to whether, a diagnosis having been made, operation can benefit them.

The diagnosis, in these cases, of the presence of some organic lesion and its situation must depend upon the history of the case, or upon a characteristic and constant aura or "signal symptom," or else upon the evidence of a trauma in the scalp. Such traumatic evidence, further, must stand in a reasonably certain relation to the epilepsy, for nothing is more common than scars in the scalp of the epileptic; he may possibly get a new one every time he falls in a fit. The points of this special diagnosis are often unobtainable; but they may consist in persistent or recurring headache over one particular scar, in tenderness of this scar, in its constituting an epileptogenic zone, but above all in a correspondence of its site with the physiological basis of the patient's fits when they

* Spratling, in Jour. of Insanity, July, 1903, vol. lx., p. 27.

† F. Krause, in Berl. klin. Woch., 1905, No. 44.

are ushered in by a localizable aura. The history of trauma is often a very clear indication of cortical centres whose physiological function is known, such as the various motor, sensory, visual, aphasic, or psychic auræ. These are the points upon which Friedrich lays stress.* Yet there will always remain an enormous class of cases of essential or genuine epilepsy in which no amount of investigation suffices to discover the least evidence of a focal cause. Doubtless in many of these there is an underlying organic cause, such as the birth hemorrhages, or the encephalitis of infancy and childhood following particularly the infectious fevers. But in the vast majority one can find nothing beyond the fact that the fits began within the first ten or twenty years of life, and that there is alcohol, lues, or insanity in the family history.

For the epileptic fit in its general aspects Kocher,† about fifteen years ago, proposed the removal of a large area of bone over a silent region, usually the right fronto-temporal, so as to allow space for the enclosed brain. His theory was that the epileptic fit of whatever causation was due to an increase in the intracranial tension, particularly in the cerebrospinal fluid, and that by giving more room one might prevent or abort the attacks. An organic lesion might be present, but it occupied a secondary place in causation. It is true that Stadelmann has proved that the tension of the cerebrospinal fluid during an epileptic attack is enormously raised, but this is clearly the result of the attack, not its cause. It is, however, conceivable that a very great rise in the tension of the cerebro-spinal fluid may act by establishing a vicious circle once that tension is begun, though it be not the prime cause. In this sense, it is clear that the removal of a large portion of bone might serve to lessen the number and severity of attacks, or possibly even to abolish them entirely by preventing the establishment of such a vicious circle.

The practical results have been somewhat in favor of Kocher's practice, though his theory is generally denied. Many have argued that a defect in the cranial wall was more likely to provoke epilepsy than to prevent it, and have brought facts to show that the closure of cranial defects may cure the disease.

The most striking article of recent years upon the surgery of genuine epilepsy is that of Friedrich, who reports upon eight cases observed for a period of over five years. Four of his cases were of the severe type and combined with idiocy, two others were also severe, and one was complicated by profound psychical changes, although the intellect was normal. Three possessed normal intellect. All were males from sixteen to thirty years of age. In all, the onset of the disease dated from seven to twenty-five years previously, in six, hereditary influences were strong. In four, there was discovered a history of traumatism; in the others the mode of causation was not clear. He operated upon Kocher's

* Friedrich, in Arch. f. klin. Chir., 1906, Bd. lxxvii.

† O. Schaer (from Kocher's clinic), in Arch. f. klin. Chir., Bd. lix., p. 665.

principle, removing a considerable area of bone together with the dura. His results were remarkable: There were two absolute failures; four were improved, and of these one was troubled only with slight nocturnal attacks, the world at large did not know that he was epileptic; in another the improvement almost amounted to cure; in two others the improvement is characterized as "great"; in one other the improvement was merely transient and of no long duration; finally, there was one complete cure. This last had suffered from apparently genuine epilepsy for fourteen years, and was so much deteriorated mentally as to be counted an idiot; the epilepsy had apparently followed a blow on the right side of the head. Friedrich found periosteal hyperostosis, situated over the left arm centre; the removal of this with a large part of the bone around it resulted in cure. The conclusion seems evident that the clinical type of essential or idiopathic epilepsy, as regards the fits themselves, does not constitute a contraindication to operation, even in the presence of dementia or idiocy, provided that there can be found anything pointing to a definite organic cause and a definite situation.

The value of such an article based upon cases reported by one man, operated on by the same method, and observed not less than five years after operation, is great. It shows that there exist, even in the great group of genuine epilepsies, possibly a number of cases for whom operation has a reasonably good chance of being beneficial.

Brief reference may be made to the one form of surgical treatment which has been advocated of set purpose for the treatment of idiopathic epilepsy. I refer to the removal of the sympathetic ganglia. This proposition was first made by Alexander in 1880 upon the theory that the immediate cause of the epileptic fit lay in an anæmia of the brain, and that the excision of the ganglia would produce more or less permanent cerebral hyperæmia by cutting out the constrictor impulses. Kussmaul and Tenner's observations, which showed that the cutting off of all the blood supply to the brain resulted in generalized convulsions, were adduced as evidence. Of course we know that cerebral anæmia does have this effect; one sees, for instance, epileptiform movements developing in cases of heart block; also, for instance, in the *schechita* or Jewish method of slaughtering cattle; and Doyen asserts that in one patient, on whom he was operating, an epileptic fit having supervened while the cortex was exposed, he was able to see a blanching of the cerebral vessels.

Excision of the cervical sympathetic ganglia was taken up with enthusiasm by Jonnesco, Chipault, and others. The former, in 1900, reported 97 operations of this nature and claimed a cure in a considerable percentage. Winter has lately compiled the statistics of this operation. In 122 cases observed there were 8 three-year cures, that is 6.6 per cent, and in 14 per cent no fits had appeared in from one to two years; 19 per cent were "improved" and 5.7 per cent died, although none as the direct cause of the operation. Fifty-five per cent showed no change. In spite of such figures, concerning, moreover, in the majority of cases genuine epilepsy, the procedure has found but little favor with epileptologists and surgeons. It is probable that the whole matter is based upon faulty physiology. Still it would seem, if surgery is to touch the cases of genuine epilepsy at all, that this method, in view of its relative harmlessness, might justifiably be employed in skilled hands. The operation is a dissection of no small difficulty. After all, any treatment of essential epilepsy, beyond the mere meeting of symptoms with sedatives, must be absolutely empiric for the time being.

A few words in conclusion must be devoted to a consideration of the *status epilepticus*. It is natural that, when epileptic convulsions recur at such short intervals as to constitute almost an unbroken series for any length of time, the outlook becomes extremely dark; in fact the patients thus afflicted usually die ultimately of exhaustion. While the condition is characteristic of many cases of the genuine form, it also not infrequently, as in a case observed by the writer, assumes a Jacksonian type, a condition which has been called *status hemiepilepticus*. Certain operations, still few in number, have been carried out for the relief of this condition, usually under the diagnosis of an organic cause. They have consisted in a purely empiric removal of bone for decompression; and the results would seem to show that death can not infrequently be warded off, at least for the time being. In Schultz's case, apparently moribund, the patient was delivered from the pressing danger of his *status*, though his epilepsy was not cured; and he died of it three years later. Sedative drugs having failed, chloroform should always be tried first. In *status epilepticus* there would seem to be established a sort of vicious circle which may be broken by sufficient lowering of the blood pressure.

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XXI. CEREBRAL TUMORS.*

The tumors that develop within the cranium may be classified according to the ground tissue from which they arise. There are the gliomata which spring from

* In the preparation of this section, the writer has received valuable assistance from a synopsis of the cases of cerebral tumor in the Royal Victoria Hospital prepared by Dr. Robins, Associate in Neurology in the hospital, for an unpublished article. Dr. Robins's kindness is here gratefully acknowledged.

the supporting structure of the neuroglia; and there is the neuroglioma ganglionare. The latter is probably of congenital origin, and occurs either as a circumscribed tumor or as a diffuse enlargement of parts of the brain. Histologically it is formed of neuroglia containing small groups of ganglion cells. It is extremely rare and has no clinical significance. In the second place there are the tumors that arise in connective tissue—fibroma, sarcoma, endothelioma, angioma, and osteoma, and the various combinations of these with sarcoma. In the third place there are the epithelial tumors, carcinoma and cholesteatoma. All these represent the major part of the true neoplasms. In addition, there are found in the brain the infectious granulomata, and the cysts of parasitic origin, which from their clinical significance are usually reckoned with the tumors. The former are made up of the tuberculomata and the gummata chiefly, while glanders and actinomycosis are only occasionally represented. The cysts may be of echinococcal or cysticercal origin. If one take the gummata and the tuberculomata as belonging to one group they undoubtedly form by far the largest class; following them in frequency come first the glioma and next the endothelioma.

The Infectious Granulomata.—(*a*) SYPHILIS.—The luetic tumors of the cerebrum have already been considered in the chapter on Luetic Meningitis, and need not here receive further discussion.

(*b*) TUBERCULOSIS.—The effect of the tubercle bacillus upon cerebral substance does not differ essentially from its effect on other tissues. The same caseation occurs, followed by the same breaking-down, with the formation of tuberculous abscess, or, in the opposite event, by the same process of healing, leading to ultimate fibrosis or calcification. It is probable that the occasional instances recorded of spontaneous cure of symptoms, or of a cure following a simple decompressive operation without discovery of the tumor, have been frequently due to the healing of a tuberculous focus. If an abscess is formed, it may become encapsulated and apparently lie quiescent for a long time. Some of the so-called idiopathic abscesses in the cerebrum, without discoverable focus of infection elsewhere in the body, are undoubtedly instances of tuberculomata completely broken-down. On the other hand, the extension of such an abscess to the surface and its rupture into the meningeal spaces, not infrequently lead to diffuse and fatal meningitis. The tuberculoma is not infrequently single, and the tumor may attain quite a large size; I have seen two as large as a walnut. Yet in the majority of cases only one is present. There may occur regular agglomerations of tubercles, which occupy in rare instances a large part of one hemisphere. The lesion is sometimes apparently primary; at least no focus can be found elsewhere in the body at post-mortem examination. Ordinarily, however, the contrary is the case. The cerebellum is the part of the brain in which the tuberculoma is most frequently seated (see Fig. 62), and children are more often affected than adults. In their growth the tuberculomata usually cause the ordinary symptoms of tumor.

As to operating, many objections have been urged to such a course, the arguments being that there is so frequently tuberculous disease elsewhere in the body, and particularly that the suspected tuberculoma is very often only one of several simultaneously present in the brain; that, therefore, though one may relieve the symptoms of the moment, recurrence is inevitable; and, moreover, that there is danger of the development of tuberculous meningitis or miliary tuberculosis as the more or less natural complication of the operation. Such arguments, it is true, have found some justification in the results of operating hitherto; yet in the main they can hardly preserve their validity in view of surgical progress in this line, and in view of the facts that a lesion is often enough

FIG. 62.—Large Tuberculous Nodule in each Hemisphere of the Cerebellum. From a boy, aged eight, who had presented marked cerebellar symptoms during life. (Dr. Shirres' case.)

single and accessible, and that the operation is occasionally curative. The striking ease with which such a lesion may be removed is well illustrated in one of the Royal Victoria Hospital patients (service of Dr. Bell) who presented sufficiently definite cerebellar symptoms to warrant exploratory operation in that region. When the dura was opened the tumor immediately came into view, and could be shelled out with the finger with the greatest ease. The patient left the hospital, after a few weeks' stay, with persisting fever, and died in another city two or three months later, in all probability of generalized tuberculosis, yet with relief of his cerebellar symptoms.

Actinomycosis.—A localization of actinomycosis in the brain is decidedly rare.

De Quervain* made a study of the cases recorded up to 1898, fifteen in number. The lesion was practically always secondary; once it was primary. Clinically it simulates meningitis or encephalitis. In the brain substance it is usually circumscribed, yet often there are several foci; and frequently the disease spreads widely through the meninges. The prognosis is apparently hopeless, and the disease runs a course of but a few months after the appearance of cerebral signs. Keller's patient was trephined for a parietal abscess, and there ensued temporary recovery for eight months. The treatment should be limited to trephining and eradicating the lesion if it is accessible and is causing severe headache; but the operation can be considered only palliative. Of course iodides should be used.

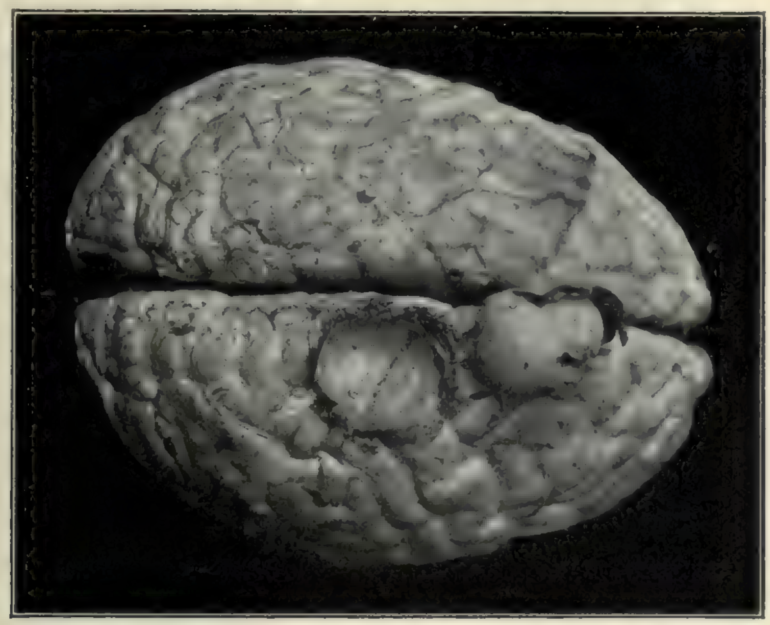

Fig. 63.—A Small Endothelioma Growing from the Dura Mater with Great Slowness, and gradually creating a nest for itself, without causing clinical symptoms. The patient was an elderly female who died of cardiac and renal disease, the cerebral growth being unsuspected. Compare with Fig. 65. (Path. Dept., Royal Victoria Hospital, 114, 1905.)

Glanders.—The granuloma of glanders has already been referred to in the section on the Cranial Bones. The disease very rarely affects the cerebrum. Robins found that, in forty-four autopsies upon cases of chronic glanders in man, intracranial lesions occurred seven times. Once an actinomycotic cyst was was found in the right hemisphere; once there was a leptomeningitis of the base. In the other five cases the disease was represented by localized purulent collections, sometimes inspissated, and situated between the dura and the skull, generally over the convexity.

Endothelioma.—This is a peculiar form of growth that arises usually from the inner surface of the dura mater, but occasionally from the pia-arachnoid. It con-

* De Quervain. "Travaux de Neurologie Chirurgicale," vol. iii., 1898. (With bibliography.)

sists, in the former instance at least, of spindle cells in which lie scattered about peculiar concentrically arranged bodies called whorls, which represent apparently the cells of the tumor arranged circularly and undergoing hyaline degeneration. Blackburn * calls these growths spindle-celled endothelial sarcomata, yet, although their histological picture is to a slight degree suggestive of sarcoma, their essential benignancy, clinically considered, hardly allows the title of sarcoma. In 1,700 autopsies on the insane, Blackburn found 28 cerebral tumors, 17 of which belonged to this class. In this growth the tumor acquires a condensation capsule between it and the brain tissue, and practically never destroys the nerve

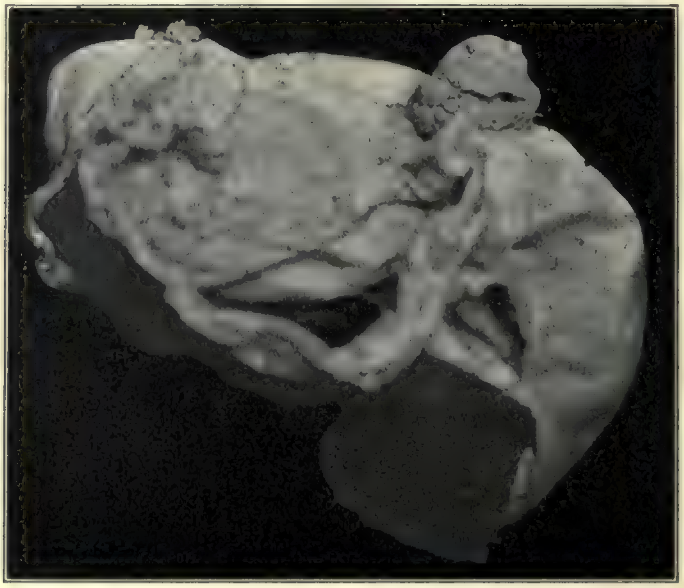

FIG. 64.—Endothelioma Growing from the Inner Surface of the Dura Mater which is here turned inside out. The tumor was an accidental finding at the autopsy of a patient who had died of typhoid after two days in hospital. It illustrates the early stage of such a tumor as that seen in Fig. 60, and indicates how tolerant the brain may be of a slow-growing mass which pushes aside rather than destroys the cortical tissue. (From the Path. Dept., Royal Victoria Hospital, 39, 1905.)

fibres save by pressure. Its attachment to the dura is nearly always slight, so much so that doubt has been expressed as to the certainty of its origin from the dura. It is quite benign, forms no metastases, and, surgically speaking, is easily removed. Some of the best results in cerebral surgery have been obtained in the removal of these tumors. The primary tumors of the optic nerve which form the subject of Byers' excellent monograph,† and the cerebello-pontine-angle tumors of the acoustic, are presumably variants of this class. They may be situated anywhere in the meninges. I find them in the Royal Victoria records most often over the convexity, but they are seen also at the base. One of these com-

* Blackburn: "Intracranial Tumors in the Insane," Washington, D. C., 1903.

† Byers: Royal Victoria Hospital Monographs. No. 1, 1901, Montreal.

pressed the pituitary body and was taken for a hypophyseal tumor. More than other cerebral tumors they seem to owe their origin to trauma. The writer is able to present some illustrations which seem to bear out this theory, although a traumatic history was present in but one case. (Figs. 57, 58, 59, and 60.) In these instances the tumor had evidently grown from the point of injury caused by the indentation of a spicule of bone from the inner table. Their comparative frequency is surgically fortunate, and is an important clinical fact. In the past, however, it has been so firmly believed by the internist that no cerebral tumor save the Rolandic ones offered any prospect of surgical interference,

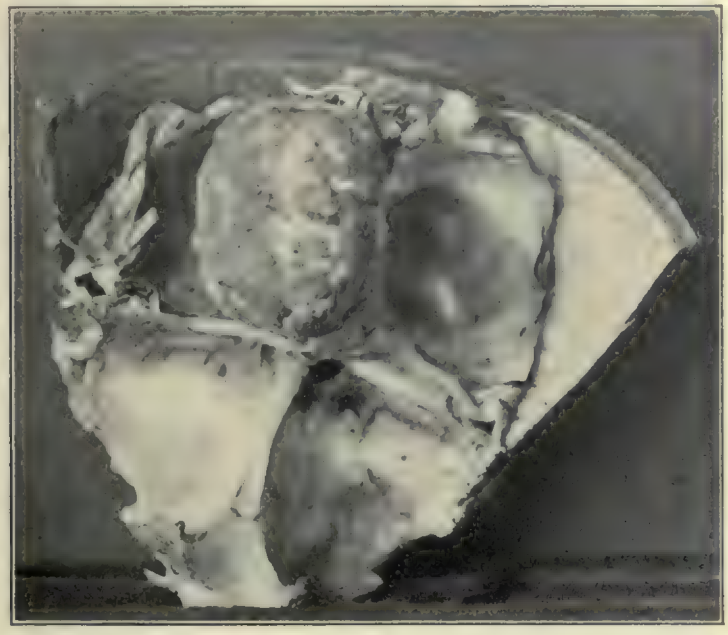

FIG. 65.—Large Endothelioma, 4x4x3 cm. ($1\frac{3}{5}$ in. x $1\frac{3}{5}$ in. x $1\frac{1}{5}$ in.), Growing from the Dura Mater, just above the tentorium, and excavating the brain tissue in the region of the occipital lobe; posterior and mesial aspect, as seen in Fig. 66. (From the Pathological Dept., Royal Victoria Hospital, No. 64, 1899.)

that the benign nature of many of these tumors has been revealed only at autopsy. It is perhaps this very benignity of growth, combined with the comparative ease of surgical removal, which forms the strongest justification for a routine attempt to remove any cerebral growth that can be localized and is surgically accessible. Several illustrations of this variety of growth are here introduced in order to emphasize this point. (Figs. 63–66.)

Glioma.—The glioma, in marked contrast with the preceding form of growth, is essentially infiltrating. In some instances a capsule is present, but in the majority of cases a capsule is lacking, and often the growth can hardly be distinguished from the surrounding brain substance. The tumor seems to show many grades of malignancy. As to this, however, it is not malignant in the ordinary sense, in that it does not form metastases; yet in the manner of its local growth it is essentially malignant. It has been compared with the process of the decay of fruit. In one patient in whom, as shown at autopsy, both optic thalami were extensively infiltrated by gliomatous overgrowth, it was impossible upon macroscopical observation of the brain to find the location of the tumor, except in so far as a mere suspicion was justified that the optic thalami were altered, it was only on microscopical examination that the condition was determined. It resembles also at times the pathological aspect of acute œdema, which sometimes involves one side of the brain alone or

Fig. 66.—Area of Depression in Right Occipital Lobe, Mesial and Posterior Aspect, Caused by a Dural Endothelioma. The tumor is shown in Fig. 64. The patient was a woman of sixty-four, with advanced arteriosclerosis, myocarditis, and chronic nephritis. The symptoms of cerebral origin consisted in visual hallucinations, followed a month later by optic neuritis. Hemianopsia was later established, with general contraction of both fields. She sank shortly into a condition of senile dementia, and died within six months from onset of cerebral symptoms. Vomiting had been present for only two weeks before death and was ascribed to uræmia. (Path. Dept., Royal Victoria Hospital, No. 64, 1899.)

even a smaller area. (Collier's illustration, Fig. 75.) Microscopically, however, one can distinguish two grades of malignancy in many of the cases. In those of more chronic growth the gliomatous tissue is old; the glia cells are, comparatively speaking, in the background, and the glia fibres, which are believed to be developed only as the cell becomes adult, are numerous. At the other extreme one finds numerous large cells without material development of glia fibres, the growth, in short, resembling a large-celled sarcoma. The writer believes that the terms sarcoma and glio-sarcoma are erroneously given to many gliomata of this latter class. From an embryological standpoint such use of these terms is without justification. In the case of a patient in the service of Dr. Stewart* at the Royal Victoria Hospital, in whom a glioma of the left motor region was removed three times by Dr. Bell, the writer was able to trace a change in the microscopical characters of the growth from the primary tumor to the one which was ultimately obtained at autopsy, including the portions removed at the two operations for recurrence. (See Fig. 67.) It was interesting to observe how the chronic appearance of the first sections, with small cells and numerous glia fibres, became replaced by the malignant one of large cells and, ultimately, an almost total lack of glia fibres. It was the development of the comparatively benign form of gliomatous overgrowth to the markedly malignant; the transition from the text-book description of glioma to the text-book descrip-

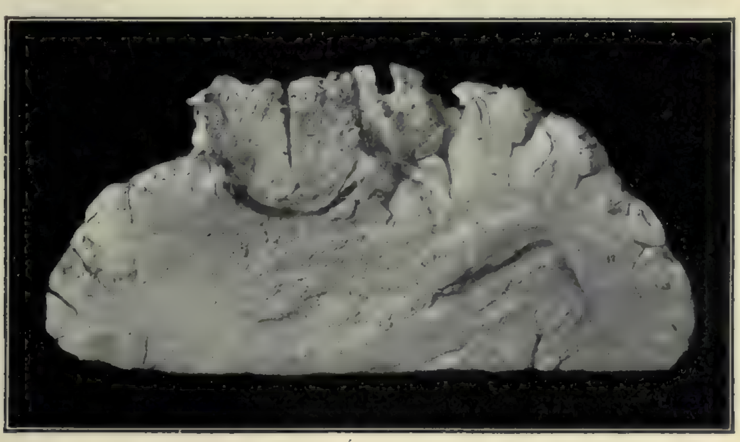

FIG. 67.—Recurrent Glioma of Rolandic Region. (Path. Dept., Royal Victoria Hospital.) This patient had had three operations within a year and a half. On each occasion a moderately large tumor was shelled out with the finger. The photograph shows the recurrence of which patient ultimately died.

tion of sarcoma. It is probable, therefore, that the term glio-sarcoma is rarely justified, and that the majority of the so-called glio-sarcomata are in reality pure gliomata of exceptionally rapid growth.

The gliomata are apt to be very vascular, and are consequently subject to hemorrhages, with ultimate cystic development in the interior of the tumor. (See Fig. 68.) A hemorrhage of this sort may clinically simulate the ictus of cerebral hemorrhage. Cysts are also formed in the tumor by local degeneration of its cells. The progress of such a growth may for long be very slow; it may even become stationary for long periods. In the patient whose brain is illustrated in Fig. 69 the symptoms had been present for six years, and death ultimately was more due to a complication of hydrocephalus than to the actual local

* Stewart, in Trans. of the Assoc. of American Physicians, 1901.

effect of the tumor, in spite of the fact that the latter was situated in the floor of the fourth ventricle, and had largely converted the medulla into gliomatous tissue.

The operative treatment of gliomata can show but sorry results. In 19 cases of glioma and 4 of sarcoma, 23 in all, reported by Horsley at the Queen's Square Hospital, recurrence took place in 20 within two years. Still, by a fortunate combination of early diagnosis and exceptionally wide removal, a combination that can rarely be obtained, Horsley has been able to prevent recurrence in one or

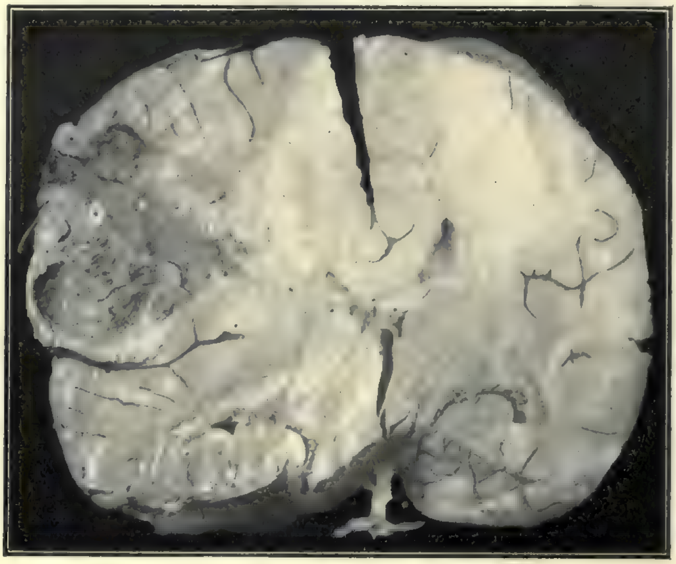

Fig. 68.—Cystic and Hemorrhagic Glioma of Left Motor Region; Bounded below by the Fissure of Sylvius. Note the infiltrating character of the growth; the dislocation of the lateral ventricles and longitudinal fissure; the compression of the temporal lobe. Illness of only seven months' duration; beginning with subjective sensations in right fingers, soon followed by paresis of right hand and arm. Within three months, onset of Jacksonian fits (infrequent) and of motor aphasia. No word deafness nor word blindness. Progression so as to involve face and leg slightly, and also tongue. Operation, five months after onset, evacuated cyst of left motor arm centres containing about two ounces fluid, with great temporary improvement; recovery of speech and sensation. Death two months later with continued compression symptoms. (Path. Dept. of the Royal Victoria Hospital, No. 39, 1902.)

two cases. Upon the whole, Walton expresses the very justifiable opinion of the majority of neurologists that it is useless to attempt the radical removal of infiltrating gliomata, that one might as well try to prevent fruit from rotting. Such a statement may, of course, suffer exceptions; an infiltrating glioma may justifiably be removed by one versed in this work; witness Horsley's two or three successes. Moreover, a few of the gliomata show some tendency to localization, and their confines are easily determined; in such, operation may be attempted. The purely decompressive operation in most cases yields very gratifying results.

Cystic Tumors.—The large porencephalic cyst resulting from birth hemorrhage, or the cyst that represents the end stage of traumatic cerebral hemorrhage, can hardly be called a tumor, although it not infrequently gives rise to epileptic manifestations, and although in rare instances, by gradual addition to its contents, it may simulate a tumor. Apart from those which are caused in this manner and from those which perhaps owe their origin to a localized encephalitis, cerebral cysts are chiefly due to parasitic disease, and are therefore especially frequent in tropical countries. The echinococcus is chiefly concerned, occasionally the cysticercus. The cysts of this causation increase in size and cause symptoms of tumor. The prognosis with operation is not so serious as might be thought.

Occasionally one meets with a congenital cyst as the result of inclusion of a

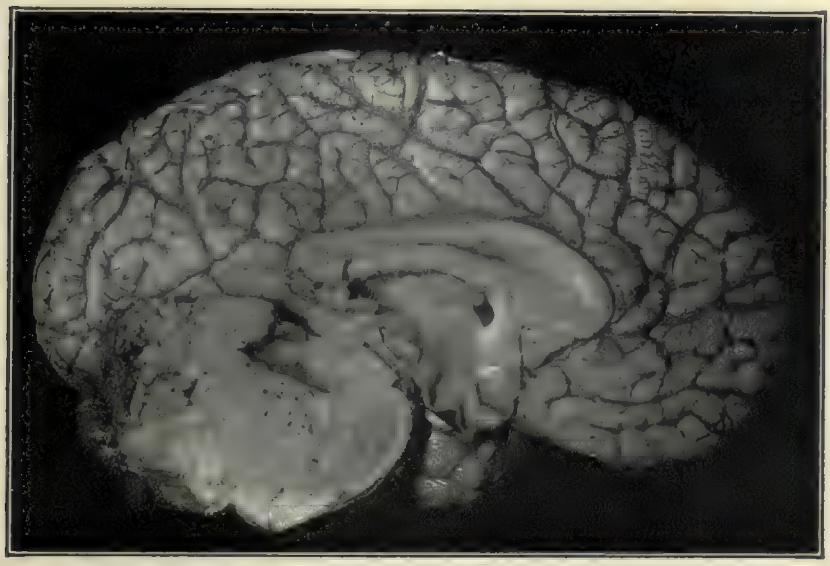

FIG. 69.—Cystic Glioma, Probably Originating in the Floor of the Fourth Ventricle, which, however, could not be demonstrated; causing great dilatation of the aquæduct of Sylvius and of the ventricles by obstruction; and so compressing the cerebellum as to give marked cerebellar symptoms. Note posteriorly the great damage to the cerebellum, produced by hernia through the occipital operative opening. (Author's case.)

bit of the wall of the primary vesicle. Microscopically such cysts are lined with ependymal cells. The cyst may attain a fair size, and in one case observed by the writer (Dr. Buller's service) it became secondarily infected from a frontal-sinus osteoma, associated with suppuration, and contributed certainly in no small degree to the death of the patient. Occasionally what appears to be a simple cyst is found, on microscopical examination, to be really the end result of the almost complete degeneration of a glioma. Such are particularly observed in the cerebellum. The writer has operated upon a patient who presented all the signs of an extra-cerebellar tumor, and in whom it was ultimately demonstrated that the condition was a cyst of the arachnoid extending over the whole base of the skull from the region of the olfactory bulbs back to the posterior limit of the occipital fossa, leaving only the left cerebellar chamber free. This had produced symptoms of general pressure, together with palsy of the right sixth, eighth, and ultimately the seventh cranial nerves; and in addition there were symptoms peculiar to a right cerebellar lesion. It was apparently only in this position, beneath the tentorium, that it met sufficient resistance to cause localizing signs. Pathologically, the sections revealed nothing upon which a certain diagnosis might be based, but the conditions found suggested the degeneration of what may originally have been an endothelioma of the leptomeninges. Such cysts are extremely rare. Finally, there occur cysts the causation of which it is quite impossible to trace. (See Fig. 80.)

Sarcoma.—Sarcoma is not infrequently primary in the connective tissue of the brain (either intracerebral or in the meninges), yet more often it begins in the

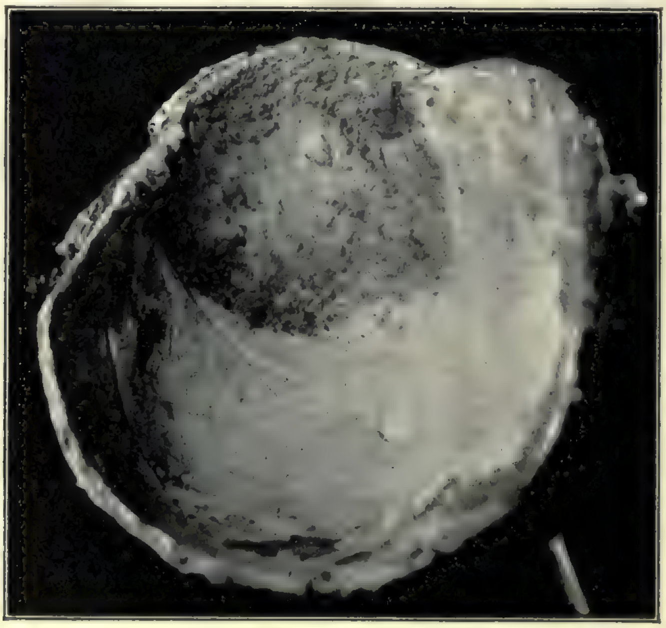

Fig. 70.—View of the Inner Surface of the Calvarium, Showing Extensive Erosion of the Inner Table, with minute hemorrhages, caused by the growth of a cerebral sarcoma. (One section of the brain in this case is seen in Fig. 71.) (From the Path. Dept. of the Royal Victoria Hospital, 41, 1905.)

bone and invades the brain secondarily. When primary in the meninges or the cortex it is very apt to cause extensive erosion of the bone, an illustration of which is seen in Fig. 70, and sometimes it may completely destroy the latter and appear under the skin. Whether it be secondary or primary, there are apt to be multiple foci. (See Fig. 72.) Its malignant characters are as pronounced in the brain as elsewhere, and its radical removal is rarely possible.

Carcinoma.—This form of malignant tumor is practically always metastatic when it occurs intracranially. The metastasis also occurs more often in the cranial bones than in the brain itself; but from the bone the disease is apt to invade the brain secondarily, although at times the dura sets an efficient barrier.

(See Fig. 5.) Krasting* has analyzed the metastatic sarcomata and carcinomata as they occur in the cranium, of 53 cases which he collected the metastatic growth was carcinomatous in 39 and sarcomatous in 14.

Fibroma.—This form of tumor is of infrequent occurrence. Horsley reports 4 cases in a total of 55 tumors. One of these is pictured in the thesis of Auvray (see Fig. 73); it was removed by Horsley. Operative treatment is known to be successful; in Horsley's 4 cases there has been no recurrence.

Angioma.—Angiomata also are rare. Lavillette† has given a résumé of the recorded cases, eighteen in number, in an excellent thesis. In one or two instances the growth in the pia-arachnoid has apparently been associated with

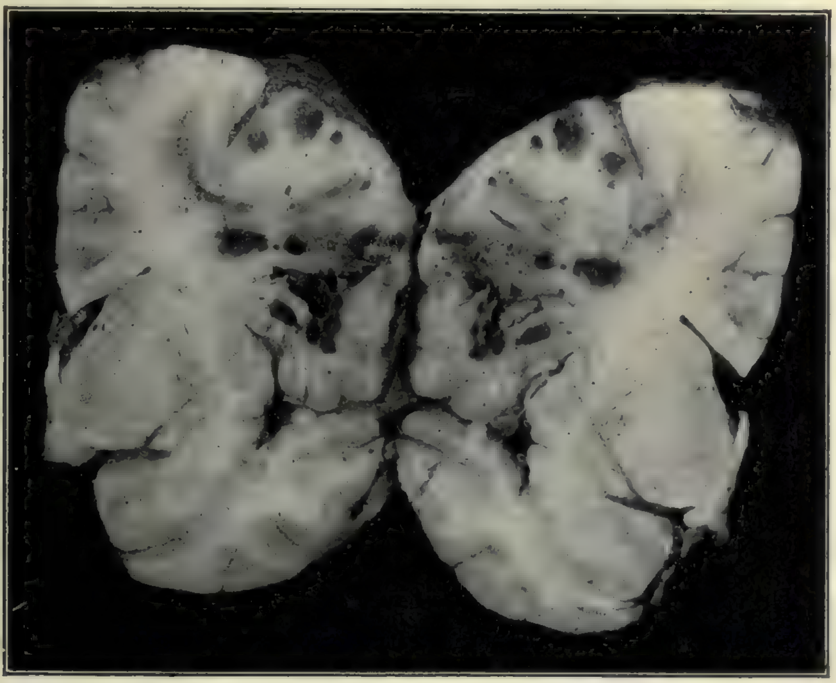

FIG. 71.—Multiple Hæmorrhages in a Diffuse Endothelial Sarcoma. Patient died within a few hours, with symptoms of apoplexy, from hemorrhages into right internal capsule. The tumor was represented by multiple foci: there were many neoplasms in the rest of the body; in cranial and other bones, subcutaneous tissues, and abdominal viscera. (Compare Fig. 70.) (Path. Dept., Royal Victoria Hospital, 41, 05.)

superficial vascular nævi in the trigeminal distribution—an observation analogous to those of Baerensprung and, more lately, of Harvey Cushing, in relation to vascular tumors of the dura mater. Angiomata are situated either in the pia or in the cerebral substance itself, and cause symptoms resembling those generally associated with an intracranial tumor.

Psammoma.—This tumor may be regarded as only a variety of endothelioma in which "microscopical whorls" become calcified.

* Krasting, in Zeit. f. Krebsforschung, Bd. iv., No. 2.

† Lavillette: "Les Angiomes Intracrâniens." Thèse de Paris, 1906.

Cholesteatoma.—This form of epithelial tumor, so frequently met with in the middle ear, is very rarely found inside the cranium. Borchhardt* reports a case in which the growth was situated in the posterior fossa. This may cause the symptoms of tumor, and can be diagnosed only at operation or at post-mortem examination.

Dermoids.—An epiblastic inclusion may occur inside the cranium. In the embryo the dura and the skin are in contact. Hartley † reports an instance

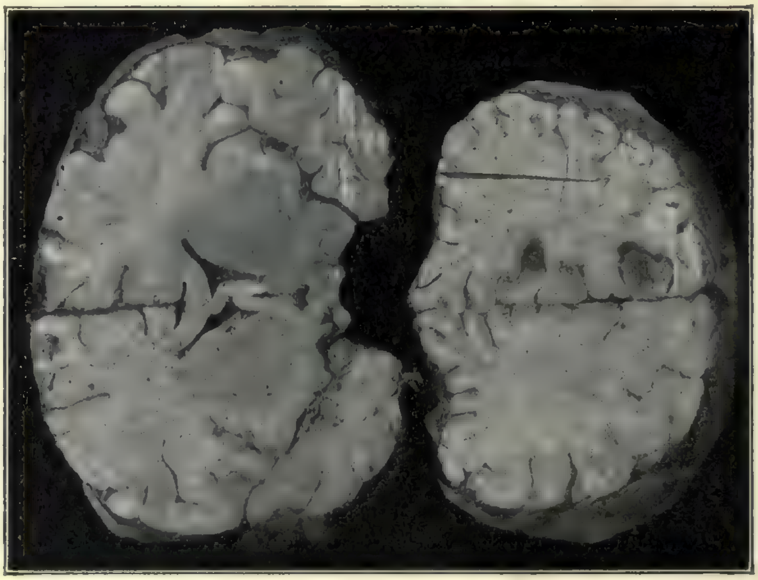

Fig. 72.—Multiple Sarcomatous Nodules of Cerebrum. The primary growth originated in the right choroid plexus, and was denominated perithelioma. It involved a large portion of the posterior part of the right hemisphere. There were numerous secondary nodules, all small, scattered throughout the cerebrum and cerebellum, but absolutely none elsewhere in the body. Symptoms had been present for a year and consisted in numbness and paresis in left arm and leg. (Path. Dept., Royal Victoria Hosp., 47, 1903.)

of the successful removal of one which was situated in the left frontal region subdurally. I reproduce here the illustration of a dermoid cyst in the cerebellum. (Fig. 74.) In both cases it is noteworthy that a communication with the outside skin is clearly indicated in the specimen, pointing to the fact of its embryonic inclusion.

Bielschowsky ‡ has described peculiar *epithelial* tumors arising in the *choroid plexus*, apparently peritheliomata, according to Lubarsch. One of these showed marked malignant characteristics by invasion of the cerebral substance. The others were benign.

* Borchhardt, in Arch. f. klin. Chir., Bd. lxxvii., Heft 3.

† Hartley, in Annals of Surgery, 1896, vol. xxiii.

‡ Bielschowsky, in Arch. f. klin. Chir., Bd. lxxxi.

Symptoms of Cerebral Tumors.

The three questions that confront the physician when suspicion arises concerning a cerebral lesion are: Is there a tumor present? If so, what is its situation? And what its nature? The answer to the first lies mainly in the presence or absence of certain general symptoms which we know by experience to be commonto all, or most, tumors in this region of the body, symptoms which indicate really a diminution of the intracranial space. These form, taken together, what Duret calls the syndrome of cerebral tumor; they are the "cardinal signs"—headache, vomiting, and optic neuritis. To these some add vertigo, convulsions, and diminution of intellectual capacity going on to stupor. The situation is recognized by the focal signs of disturbance of the various centres of cortical function.

Fig. 73.—Fibroma Removed by Horsley (actual size). (From Auvray's thesis, Paris, 1896, p. 216.)

It is often impossible to make a diagnosis as to the nature of the tumor; but certain indications are got from the clinical evolution of the case and the situation of the tumor.

1. *The syndrome of cerebral tumor* consists of the three cardinal symptoms: headache, vomiting, and optic neuritis. The first two have already been discussed in the section on the Organic Signs of Cerebral Lesions.

Optic Neuritis.—The exact mode of causation of optic neuritis is still under discussion, but in the general opinion it is believed to be a purely mechanical phenomenon, due to the forcing of cerebro-spinal fluid into the sheath of the optic nerve, and it is always associated with an increase in the tension of that fluid. It has long been recognized as one of the three cardinal signs of cerebral tumor, though it may occasionally be absent till near the end, or may indeed never appear. The most complete treatise upon this sign that we possess is the article of L. J. Paton (*Lancet*, Feb. 8th, 1908, p. 429), based on the observation of 252 consecutive cases of tumor at the Queen's Square Hospital. In 202 of these the localization was definitely made, and in 148 this was confirmed by operation or by autopsy. Of these, 38 had no neuritis; in 12 it was very slight; and in the rest it was marked or had even gone on to the stage of atrophy. Those in which neuritis was absent were in the main situated subcortically or in the pons. When subcortical tumors developed choked disc, it always meant a secondary involvement of the gray matter in cortex or basal ganglia. In tumors of the cortex, the intensity of the neuritis seemed to vary inversely

FIG. 74.—Dermoid Cyst of the Cerebellum. *a*, Cavity of the cyst filled with sebaceous matter and curled hairs; *b*, prolongation of the dura mater; *c*, prolongation of the scalp corresponding to that of the dura mater, as if indicating a primitive continuity of the skin with the cyst. (From Lannelongue's "Traité des Kystes Congénitales," Paris, 1891.)

with the distance of the tumor from the anterior poleof the middle fossa, in other words, from the exit of the optic nerves into the orbits. The nature of the growth made no difference in the degree of swelling. Very important is Paton's observation that but little reliance can be placed on difference in the intensity of the neuritis as indicating the side on which the lesion is located. In frontal and cerebellar growths it was found to be just as intense on the opposite as on the same side. It must be remembered that, although it is one of the most certain signs of cerebral tumor, it may at times not appear till late in the disease. In the presence of persistent headache with or without vomiting, and in the absence of focal signs, the demonstration of some swelling of the optic disc is often the one sign that clinches the diagnosis, and converts the somewhat haphazard idea of "neurasthenia" or "biliousness" into the very definite one of cerebral growth. The importance, therefore, of repeated examinations is great. Not less important is it that the physician should possess a sufficient degree of skill in the use of the ophthalmoscope to recognize a swelling of the optic disc. He must either do this work himself or have it done by an expert. Nor must he be led astray in suspicious cases by the fact that the patient's vision is not materially diminished, for it is a matter of common observation that even a high-grade optic neuritis may coexist with almost normal power of sight, so far as the patient himself knows.

The absence, at a given moment, of any one of these cardinal signs is no evidence against the existence of a tumor; but more or less persistent headache is very rarely absent throughout. It is the gliomata, with their tendency to replace nerve tissue rather than compress it, that exist for the longest period before causing symptoms.

It might be thought that the symptoms of generalized cerebral compression —the slow pulse, high blood pressure, and respiratory arrhythmia,—as described in the section devoted to that subject, would characterize in a particular way the progress, especially the increase in size, of a cerebral tumor. This is not the case, except in the terminal stages, when with the acute pressure of a complicating hydrocephalus or generalized cerebral œdema, or with the progressive anæmia of cachexia, the bulbar centres begin to receive poor or insufficient blood. In one hundred cases of cerebral tumor, Hale White found no clear instance of slowed pulse; and numerous records of blood pressure in the last few years have failed to show any constant rise above normal. If space diminution take place slowly, the brain adapts itself and the bulb is not compressed.

2. The *situation of a cerebral neoplasm* is recognized by its focal signs. The knowledge of the functions of the various "centres," and of the anatomical course of the projection fibres, affords in many instances a very accurate diagnosis of the situation of the growth. These have already been discussed in their general aspects (page 267), but certain further details call for a short discussion in this place. First, however, certain principles, specially applicable to tumors, are worth remembering. They depend chiefly on the fact of the slowly advancing usurpation of space and compression of nerve cells and fibres peculiar to neoplasms, as contrasted with the more rapid increase of inflammatory lesions, and the sudden onset of traumatic or vascular ones. Thus, it is the rule, in tumors, for the evidence of obliteration of function to be preceded by those of irritation; fits give place to paralysis. Again, account should be taken of the gradual addition of neighborhood to focal symptoms; as, for instance, the late development of motor aphasia in a case where the earliest signs were those of word deafness. All this indicates the great necessity of a very accurate history. The march of the symptoms is often no less important than the symptoms themselves; and the gradual extension of a tumor may often be read backward

with the greatest clearness. Collier,* however, has drawn particular attention to certain sources of error in this respect; he has shown that focal signs, appearing late where general signs alone have pre-existed, are often of false portent, in that they may depend upon pressure transmitted to a distance. As examples, there may be mentioned the late cerebellar signs given by a frontal growth, or the Jacksonian fits dependent on the late development of hydrocephalus in cases of cerebellar tumors. Urgent and rapidly fatal symptoms of generalized pressure, and perhaps also of focal nature, may be due to an acute spreading œdema around a tumor otherwise unsuspected. One of Collier's illustrations is here reproduced (Fig. 75), and the writer, through the kindness of Dr. C. K. Russell, is able to show a similar condition. (Fig. 76.) On the other hand, early focal signs are often entirely covered up, when the case is first seen late in the disease, by the development of others. So a hemianopsia may be masked by optic neuritis; or a cerebellar ataxia by the blindness of optic atrophy.

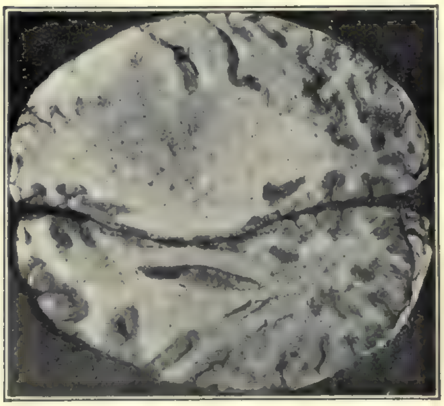

Fig. 75.—Œdema of the Centrum Semiovale, from a Small Nodule in the Right Prefrontal Cortex, Secondary to a Renal Carcinoma. The cerebral symptoms were very urgent, and death occurred in fourteen days after their appearance. There were no localizing signs during the first seven days. Afterward some degree of hemiplegia appeared. (Collier, "The False Localizing Signs of Intracranial Tumor." *Brain*, vol. xxvi., 1904.)

Finally, when the growth is in a silent region, particularly the frontal, the right temporo-sphenoidal, or parietal lobes, there may be a total absence of focal signs.

3. *The nature of the growth* is still the most difficult part of diagnosis. General considerations alone can guide one, and they are no very good guides. Tuberculomata are much more frequent in children than in adults; while, as regards gummata, the reverse is true. In such cases the history and possible coincident lesions are of great help. Still, in one case of the writer's, a girl of fourteen years, tuberculin gave a definite reaction; symptoms had been present for seven years at intervals, and yet the lesion proved to be a glioma of the medulla. The situation of the tumor affords some help. The cerebellum is the favorite seat of gliomata and of tubercles; the cerebello-pontine angle, of fibromata or fibrosarcomata. Any subcortical lesion is apt to be either a glioma, or a traumatic or an encephalitic cyst. A sudden aggravation of symptoms may represent hemorrhage in the interior of a glioma.

*Collier: "The False Localizing Signs of Cerebral Tumour." Brain, vol. xxvi., 1904.

Differential Diagnosis.

Tumors of the brain of any sort have to be distinguished from such lesions as abscess, arachnoid hæmatocele or serous cyst, and especially from hydrocephalus. Cushing has particularly emphasized the difficulty of diagnosis from the cerebral symptoms of chronic nephritis. The headache, the vomiting, even the character of the disc changes, may be identical in both; and they may happen to coincide. If focal signs remain absent it may be very difficult to distinguish the two. Usually the presence of albumin and casts in the urine must be accepted as evidence of nephritis, to the exclusion of tumor, but the case should be further watched.

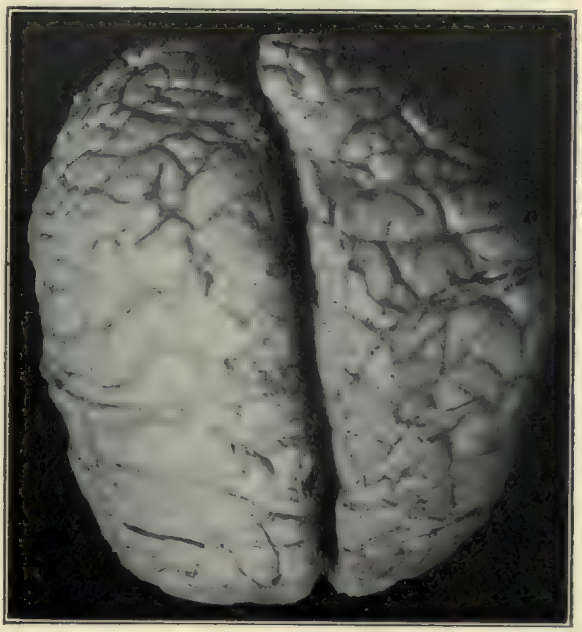

Fig. 76.—Acute Spreading Œdema.—Note the pallor, representing a Diffuse Œdema of the Right Hemisphere (left of the observer) probably the result of the rapid growth of the tumor, but possibly due to an exploratory cerebellar craniectomy done about twenty hours before death with its consequent sudden relief of compression. (Blood pressure 240 mm. Hg before operation; 140 after.) The œdema represents a factor of considerable importance in explaining the severe generalized compression from which the patient died. (Case of Drs. Martin, Russell, and Bell.) (Path. Dept., Royal Victoria Hosp., 53, 1906.)

As to abscess, the history of trauma, of ear disease, of cranial-bone infection, or of some other infection (in one Royal Victoria Hospital case a tonsillitis) is usually sufficient to base the diagnosis on. Apart from this, the course of the disease is nearly always clearly acute and febrile at some stage or other, even in the latent and chronic cases; and this knowledge is got by a careful study of the history.

From hydrocephalus arising in a primary ependymitis of unknown origin—apart from those cases the causation of which is clear (meningitis) — it may be difficult to distinguish a cerebral tumor. The bilateral character of the former, with its symmetric spastic paresis, will usually suffice; but at times the hydrocephalus apparently causes unilateral motor symptoms, and diagnosis is frequently made only at operation or post mortem.

The Use of Iodides in Diagnosis.—There is no question but that the diagnosis of cerebral neoplasms has advanced greatly of late years, and it is part of this advance that the iodides are now less used as a therapeutic test and as a therapeutic measure in this branch of medicine. Two considerations have contributed to the more rational restriction of this drug, apart from the older evidence that in the majority of cases of true neoplasm it was useless: first, the growing success of intracranial operations for tumor; second, the fact that, as Horsley showed, the true neoplasms were sometimes favorably affected, temporarily so, as well as the syphilitic lesions; and thus valuable time was lost.

Horsley's proposal, in 1890, to limit the probationary period of the iodides and mercury to a six-weeks' course (at the longest) has gradually come to more or less general acceptance. And this is well. If such a course fail, either lues is not present or the gumma is too resistant; in which case operation, when the gumma is accessible, is preferable to the prolonged use of iodides.

Lumbar Puncture in Diagnosis.—Lumbar puncture, as a method of diagnosis, is justifiable only upon condition that no more than 1 or 2 c.c. be removed. The dangers have already been fully discussed in the section on Meningeal Hemorrhage. They are probably still greater in the case of tumor. The information to be got lies chiefly in the detection of syphilis by the constant lymphocytosis which characterizes it.

Diagnosis of Lesions of the Frontal Lobe.—It is generally believed that the left frontal lobe, and particularly its anterior portion, the pre-frontal area, presides over the various processes belonging to the psyche or the higher intellect. Flechsig places here the most important of his association areas. Histological observation shows that the pre-frontal lobe sends out no projection fibres; these belong to the association system. At the same time it is to be premised, with Bruns and others, that the organ of thought can hardly be limited to any one small area of the cerebral cortex, inasmuch as intellect depends upon the co-operation of all the various centres of perception and the elaboration of sensitive and sensory impulses which have themselves, in the course of years, all contributed to the gradual formation of the intellect; and yet the accumulation of evidence goes to show that destructive lesions of the left pre-frontal lobe are associated in a rather particular way with disturbance of the "life of relation" on its mental side. These disturbances, briefly enumerated, consist in loss of memory, especially of recent events; in loss of ability to fix the attention; and in an abnormal susceptibility to any emotional disturbance, leading either to excitement or to irritability or depression. The patient's actions become in a sense automatic; he loses control. Such a condition may progress to insanity, in particular, to dementia. One notes in Blackburn's series of cerebral tumors, found at post-mortem examination in asylum cases, the frequent situation of the growth in the frontal lobes, particularly the left. In a series of five cases which came to autopsy in the Royal Victoria Hospital I found that in three the tumor was situated in the left, and in two in the right frontal lobe. In those cases in which the tumor was situated on the right side there appeared no special indications of psychic disturbance; in those in which it was situated on the left side there were two in which the growth was located in the post-frontal area, and in both of these there was no disturbance of the intellect. In the one which involved the pre-frontal area of the left side such mental disturbances were present.

The freedom from psychic effects in lesions of the right side is often remarkable. A good illustration of this is seen in a case of very extensive abscess reported by Roncali and described in the section on Cerebral Abscess. Here there was no intellectual disturbance until immediately before death. (See Fig. 45.)

Jastrowitz first called attention to the presence, in these patients, of a peculiar state of mind characterized by a certain jovial or humoristic spirit, a symptom which he called "Moria." It appears in about one-fifth of the cases only and is not pathognomonic.

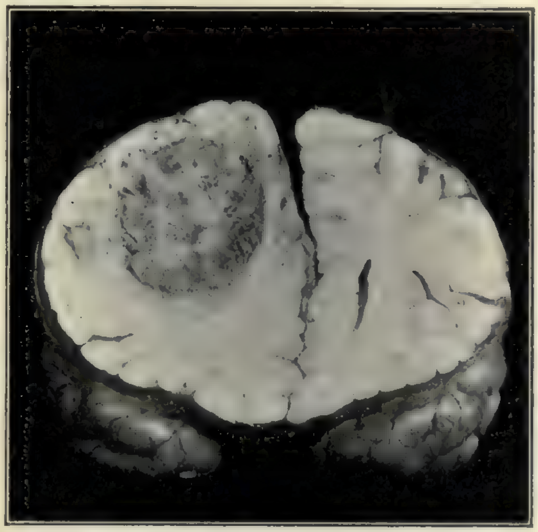

Fig. 77.—Large Glioma of Right Frontal Lobe, Simulating Left Cerebellar Growth. (Case of Drs. Martin, Russell, and Bell.) Symptoms began six months previous to death, with transitory diplopia. Two months later headache, nausea, and giddiness came on, and the patient began to stagger in walking. He became drowsy; memory and power of attention grew poor; cerebration slow; tendency to fall to the left. Definite hypotonus and incoordination of left leg. First stage of suboccipital operation done, but patient died next morning with signs of severe compression, which were probably due to the onset of acute spreading œdema. (Compare Fig. 76.) (Path. Dept., Royal Victoria Hosp., 53, 1906.)

In conclusion it may be said that such psychic disturbances have a very definite value in diagnosis, provided they appear early and are marked. Very similar symptoms are quite common in the late stages of tumor located in any part of the brain; and they simply furnish evidence of the mental obscuration which is characteristic of generalized cerebral compression.*

The second chief focal sign of frontal-lobe tumors is ataxia, as was first pointed out by L. Bruns about fifteen years ago. It is an inco-ordination affecting peculiarly the equilibrium in standing or walking, and is therefore very similar to that of cerebellar lesions; indeed it is chiefly due to this fact that tumors in these two situations are so frequently confounded. In the hospital cases analyzed by the writer the two tumors of the left frontal lobe already mentioned as being situated well back toward the motor region were characterized by ataxia and

* See, further, Schuster: "Ueber psychische Störungen bei Hirntumoren," Stuttgart, 1902.—E. Müller: Deut. Zeit. f. Nervenheilkunde, Bd. xxi. and xxii.—Grainger Stewart: Lancet, 1906, vol. ii., p. 1209.

showed in contrast an absence of psychic disturbance. (See Figs. 77 and 78.) The cerebellum indeed is connected with the motor cortex chiefly and also with the frontal cortex, the latter probably in the neighborhood of the motor area. Therefore it would seem natural that the frontal ataxia which so greatly resembles cerebellar inco-ordination should be situated chiefly in the posterior half of the lobe. An explanation of the fact is not yet possible. It would seem likely that it may be the effect of direct transmission of pressure to the cerebellum,

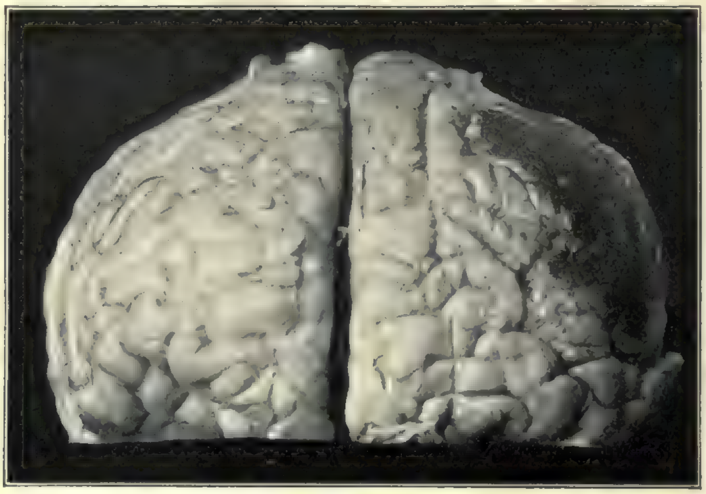

Fig. 78.—Left frontal subcortical glioma. Note bulging of cortex overlying the area occupied by the tumor. (N.B.—Brain surface darkened with hæmatoxylin for photographic purposes.) In the clinical history, an absence of intellectual deterioration; slight ataxia present; but chiefly sensory signs referred to the right leg, slight right hemiparesis, and generalized epileptiform convulsions. Note that the prefrontal area is not involved. (Royal Victoria Hospital, Patholog. Dept., 89, 1902.)

although Bruns believes that it is due to a lesion of a special half-voluntary centre for equilibration which commands the automatic one in the cerebellum.

These two chief symptoms—viz., the disturbance of the psyche and disordered equilibration—are true focal signs. Yet the diagnosis of frontal-lobe lesions is often more certainly made from the presence of signs indicative of lesions in the neighborhood. If the tumor spread backward so as to involve the motor area, one will usually get, first, irritative signs in the way of muscular spasms, which may frequently become Jacksonian in type, or even generalized; and later—sometimes years later—this may go on to actual paralysis, which may be either monoplegic or hemiplegic according as the growth is situated near the cortex or more deeply toward the internal capsule. On the other hand, if the growth extend more toward the base, one is apt to get pressure on the optic tract or chiasm, and on the olfactory bulb, so that there will ensue various disturbances of vision and of smell. Anosmia may be even unilateral, or chiefly so, as in a case which the writer had the opportunity of observing in the

Queen's Square Hospital. Not infrequently pressure on the third and sixth nerves may result in partial or complete ophthalmoplegia; or the first division of the fifth may be involved, with neuralgia in the ophthalmic distribution. Tenderness on pressure over the forehead, as I have observed, is quite frequent and has a confirmatory value in diagnosis.

In the third place, the symptoms common to all cerebral growths are here, as a rule, fairly well marked. Optic neuritis, however, does not occur early unless the basal portions are involved. Headache is frequently frontal, but also often suboccipital in situation. Unnatural drowsiness is also frequently observed; it was a prominent symptom in a patient lately operated upon by the writer. This drowsiness may become actual sleep.

Diagnosis of Lesions of the Rolandic Area.—In Duret's table of 344 radical operations for tumor of the brain there were 214 for tumors which were situated in the motor region, that is, 63.5 per cent. This does not mean that tumors of this region are so much more frequent than those of other regions, but rather that in the past they have been the only ones considered accessible to operation. As a matter of fact, it is probable that growths of the frontal and cerebellar regions are really about as frequent as the ones in question. The success of operations in this region has been such as to constitute one of the chief justifications for operation in cerebral tumors. The symptoms have been already sufficiently indicated in the section on Organic Focal Symptoms. They are so marked usually that an early diagnosis can be made, and the region is so accessible that successful operation is possible.

Diagnosis of Lesions of the Parietal Lobe.—A great deal has been written of late years on lesions of this region, and especially upon the tumors which are found here; and now sufficient observations of an exact nature have accumulated to make it fairly certain that the views expressed in the chapter on Localization are in the main correct. The work of C. K. Mills * is especially to be mentioned in this connection. The region may be divided into superior and inferior portions, as already indicated. Stereognosis is situated in the upper portion; the centres for reception of cutaneous sensations of various kinds are found in the post-central convolution and immediately behind it; and the centres for word- and object-seeing lie in its posterior portion. Mills believes that just as the motor cortex is subdivided into centres for particular groups of muscles, so are the post-central convolution and the parietal lobe generally subdivided into particular centres of sensation corresponding to definite areas on the skin surface. He believes, further, that these areas lie geographically about at the same level as the corresponding motor centres. Thus the cortical representation of sensation in the arm is found opposite and posterior to the motor representation of the arm. Naturally, the details of this conception have not yet been thoroughly worked out, although in the gross it seems to be proved.

* C. K. Mills, in Univ. of Penn. Med. Bull., April-May, 1906.

A lesion arising within this area will naturally cause neighborhood symptoms if it invade the adjoining territory. Thus, if the tumor extend anteriorly one will find entering into the picture such signs as Jacksonian spasms and an eventual paralysis of the involved muscles. If it extend posteriorly, the higher visual centres are affected; if toward the interior, it may interfere with the optic radiations running from the occipital lobe to the external geniculate body; and if inferiorly, the temporal lobe is compressed and word-hearing is interfered with. These tumors, therefore, are apt to be complicated by motor symptoms, by symptoms of sensory aphasia, or by visual symptoms, and the combinations are naturally very variable. The finer details of diagnosis cannot here be discussed.

Diagnosis of Lesions of the Occipital Lobe.—The one characteristic sign of lesions in this region resides in the interference with vision. Hemianopsia is an almost constant symptom; and this statement needs modification only in one point, viz., that very frequently the patient is unaware of his hemianopsia, and comes to the physician at a stage at which optic neuritis of advanced grade or a severe deterioration of mentality renders its detection practically impossible. Collier has drawn especial attention to this fact, and every neurologist has opportunity of confirming it. Occasionally there appear visual hallucinations as a sign of irritation of the centres in question. For instance, the patient whose brain is pictured in Fig. 66 suffered from hallucinations of vision; she saw flashes of light, often colored light, even in the dark, and saw objects upside down; occasionally she saw such objects as rats or mice, etc. These symptoms preceded the development of optic neuritis by a month. Other points of diagnosis of lesions of the optic tract in general have already been referred to. (See Fig. 55.)

Neighborhood symptoms: When the lesion extends forward these symptoms consist chiefly in visual aphasia, and are the direct effect of interference with the association fibres between the visual cortex and the parieto-temporal region concerned with the higher visuo-psychic processes. If the lesion be bilateral, complete blindness may result, as was noticed by Franz* and by de Beck in cases of concussion, the injury being applied to the back of the head, and the symptoms depending doubtless upon pial extravasation.

Fig. 79 shows a glioma of this region, or rather immediately in front of it.

Diagnosis of Lesions of the Temporo-sphenoidal Lobe.—The most certain sign of focal lesion in this lobe consists in the phenomena of auditory sensory aphasia, when this is the earliest sign; and especially is this the case if hemianopsia is lacking. Deafness is not noticed unless the lesion be bilateral; unilateral deafness points almost certainly to compression of the eighth nerve. A second valuable sign is associated with disturbance of smell or taste, which indicates that the unciform gyrus on the median surface is affected. With both of

* Franz, in Arch. f. klin. Chir., Bd. lxxxi., p. 136.

these symptoms one frequently finds signs of irritation rather than of paralysis; so that, for instance, convulsive attacks are preceded by an acoustic aura, hallucinations of hearing, or by olfactory or gustatory auræ, in which latter case the particular odor or taste is usually diagreeable. The "dreamy state" of Hughlings-Jackson is also frequently found in lesions of the uncinate region.*

The neighborhood symptoms of temporo-sphenoidal lesions, whether traumatic or due to the presence of a new-growth, consist above all in sensory and motor disturbances, especially hemiplegia and hemianæsthesia. This is more often due to an extension into the depths and invasion of the corona radiata or internal capsule than to extension over the cortex. The tumors that are situated

Fig. 79.—Glioma of Mesial Surface just in Front of the Left Occipital Lobe. It apparently caused no hemianopsia. Symptoms dated from five months previously, and consisted chiefly in progressive failure of memory, especially for names of persons and places, and for time relations such as dates (lesion of left angular gyrus?), together with the signs of general compression—headache, vomiting, and optic neuritis. (From the McGill Pathological Museum, No. 73, 64, 3. Originally from the Royal Victoria Hospital, Path. Dept., 83, 1903.)

well forward in the lobe next the sphenoid body usually compress the basal nerves, and allow a diagnosis of middle-fossa lesion only.

Diagnosis of Cerebellar Tumors.—The anatomical and physiological groundwork of the symptoms of cerebellar lesions has been already discussed in a general way. It remains to describe the symptoms from the clinical standpoint.

The general symptoms of tumors situated in the somewhat confined space underneath the tentorium are apt to be early, constant, and severe. The headache may be either occipital or frontal—more frequently the former; and it is apt to be peculiarly constant in either one of these situations. Vomiting is also scarcely ever missed; and optic neuritis, earlier here than in the case of tumors situated elsewhere, is more intense, more acute, and more constant. Horsley's

* Consult Buzzard, in Lancet, June 30th, 1906; Thomson, in Brit. Med. Jour., Dec. 21st, 1907.

opinion is that in most of the cases it develops earlier or is more advanced on the side of the growth.

The signs that are proper to a lesion of the cerebellum *per se* are, briefly, cerebellar ataxia, vertigo, nystagmus, atonia, and paresis; and it is peculiar for such of these symptoms as are motor to be situated on the same side as the lesion. In the literature the symptoms of cerebellar lesions have been until lately more or less promiscuously described, without proper distinction being made between the tumors which lie within the cerebellum and those which lie without. Stewart and Holmes * have done a very real service in differentiating clearly the one from the other. Inasmuch, however, as the intra-cerebellar and extra-cerebellar lesions cover a large common ground, in so far as they affect the cerebellar tissue proper, it is necessary to discuss them together.

FIG. 80.—Simple Cyst of Right Cerebellar Hemisphere. (St. Thomas's Hosp. Museum. Path. Series III., 2013. From Ballance, "Some Points in the Surgery of the Brain," p. 164.) "There were general symptoms of intracranial growth, headache, vomiting, and optic neuritis, but no signs peculiar to a cerebellar situation (ataxia, hypotonia, etc.). During the last three months, however, she had frequent fits during which consciousness was lost, the head thrown back, the eyes fixed, and the extremities rigid." (Rather suggestive of escape of the vermis with gradual late pressure on the intrinsic cerebellar nuclei and development of Hughlings-Jackson's "cerebellar" fits of tonic extensor character.)

The cerebellum is a favorite site for tumors and for tuberculomata. The cysts which are so frequently found in its substance represent for the most part a degeneration of gliomata, or else the end result of a hemorrhage. (See Fig. 80.) Syphilis also sometimes deposits gummata in the cerebellar tissue. These are the chief pathological lesions of ordinary occurrence. On the other hand, the extra-cerebellar lesions consist mainly in tumors. There are those of the cerebellopontine angle—often called the lateral recess or acusticus growths; those of the pontine substance; those of the corpora quadrigemina; those of the cerebellar peduncles; and lastly, those of the medulla and the fourth ventricle. In other words, cerebellar symptoms may be caused by any subtentorial lesion.

The limits of this work forbid an elaborate discussion of the differential diagnosis between all these; and we shall confine ourselves to a consideration of the two most frequent conditions, viz., tumors of the lateral recess and tumors of the cerebellum proper. The cerebello-pontine-angle tumors are practically all fibromata or fibro-sarcomata, arising for the most part in the connective-tissue sheath of the eighth nerve, very rarely in that of the seventh or fifth, and

* Stewart and Holmes, in Brain, 1904.

still more rarely in that of the ninth or the eleventh nerve. The tumor is usually benign in nature, and possesses but loose attachments to its site of origin and to the surrounding meninges; so that, from the practical side, it is easily shelled out without material bleeding. In some instances it would appear to be but one expression of a widespread fibro-sarcomatosis of the nervous system, and we have indicated in a previous section its relation to elephantiasis nervorum

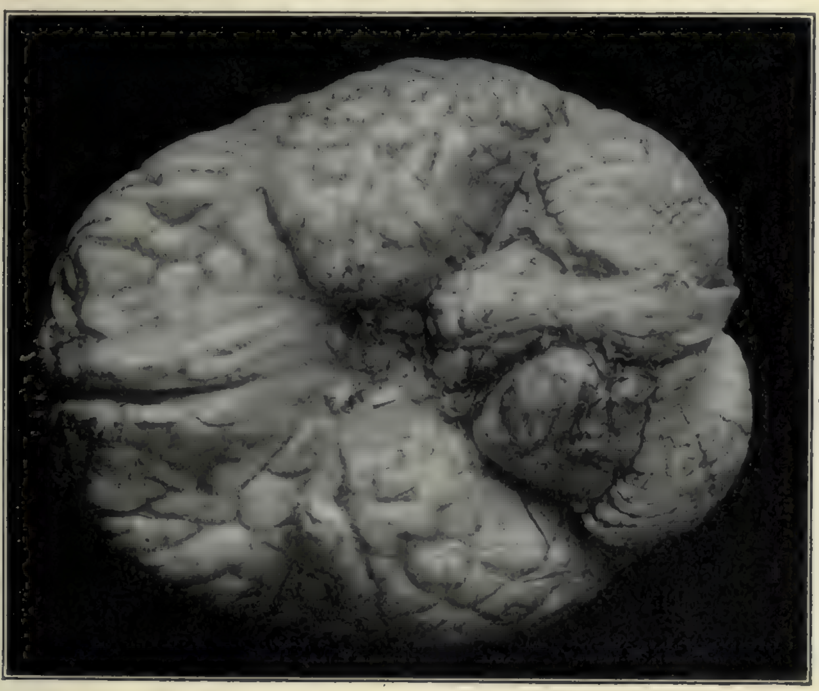

Fig. 81.—Fibroma of the Right Cerebello-pontine Angle, or Lateral Recess. Note the compression of the cerebellum, pons, and medulla. Symptoms began three years before death, with loss of hearing in the right ear; and cerebellar symptoms appeared late. See text, p. 330. (From the Path. Dept. of the Royal Victoria Hospital, No. 115, 1904.)

(Hulst, Hendrickson and Spiller). It is situated (see Fig. 81) in the angle between the anterior border of the cerebellum and the pons and it causes cerebellar symptoms by pressure upon this part of the brain.

Motor Symptoms.—Ataxia.—Cerebellar ataxia is directly due, according to the observations of Stewart and Holmes, to a lack of accurate co-operation and association between individual muscular contractions, and not to impairment of the muscle sense or of the sense of position. Its origin is therefore central, not peripheral; the patient is unable to check the deviations, though conscious of the existence of this defect. Vision is no help; the ataxia is not increased by shutting the eyes. It is an inco-ordination which appears only during active movement of a limb; it does not increase toward the end of the movement; and, finally, the limb remains steady when the object is attained.

In these particulars it is the direct counterpart of the intention tremor of disseminated sclerosis. It is most often and clearly seen in the acute cases or after operation; it affects the arm more than the leg, and is chiefly evident on the same side as the lesion. The finger-nose test is sufficient to show it in the arm, but it is most characteristic in the gait—the "drunken" gait of cerebellar ataxia, which has long been considered pathognomonic. It is probable that the staggering is due rather to inco-ordination in the action of the trunk muscles than in that of the muscles of the leg. Lordosis is frequently seen when the patient stands up. The tendency to stagger, or at least to deviate, toward the side of the lesion is characteristic when it appears; yet, if the lesion is of a chronic nature, the patient, being conscious of this tendency, often attempts to overcorrect it, with the result of obscuring the sign. It is said that the overcorrection may be detected by the fact that the patient advances and lifts the shoulder on the side of the lesion in order to prevent his stumbling in that direction. Tumors of the vermis affect the gait more than do tumors of the hemispheres: the gait is then more truly "drunken." When the tumor is situated exactly in the middle line, the tendency is rather toward falling forward or backward than to one side, although a combination of both is frequently seen.

Vertigo.—Vertigo, as one would expect, is a very characteristic sign. It is dependent upon interference with the vestibular portion of the eighth nerve in any part of its course from the semicircular canals to Deiters' nucleus, and thence to the cortex of the middle lobe. Thus, it may simulate Ménière's syndrome, seen in lesions of the semicircular canals, but the association of ataxia and other signs makes the diagnosis easy. Vertigo is independent of the ataxia, although each may aggravate the other. It is frequently a very early symptom, often appearing before ataxia. As Stewart and Holmes point out, it may appear in two forms: either a definite sense of movement of self or of objects, or an indefinite sensation which is simply described as being a "giddy feeling." In the differential diagnosis between intra- and extra-cerebellar lesions these authors find a most important aid in the characters of this symptom. Thus, when the patient complains that his giddiness consists in the displacement of external objects in front of him, it is found that, both in the intra- and in the extra-cerebellar growths, this displacement takes place from the side of the lesion to the opposite side. Whereas, when the sense of giddiness depends upon rotation of the patient himself, there appears a distinct difference. in intra-cerebellar growths the rotation of self is from the side of the lesion to the healthy side, while in the extra-cerebellar ones the reverse is true, and the patient feels as if he were turning from the healthy side to that of the lesion. The authors say that this is one of the most serviceable of diagnostic points, when present; but Bruns has pointed out that, while it may be true of acute and post-operative conditions, it is not frequently found in the chronic cases, and with this opinion the writer's experience agrees. Indeed, in cases of slow progression, one does not often find that the patient can give any definite data as to rotation or its direction. It is most often an indefinite sense of giddiness that he complains of; and this indefinite feeling has no localizing value, save where the patient tends to fall forward, backward, or to one side.

Disordered Hearing.—The acoustic portion of the eighth nerve frequently gives symptoms of marked value in diagnosis; and these correspond with what one would expect from the anatomical situation in the two cases. Thus, in the extra-cerebellar or lateral-recess tumors, there is invariably some nerve deafness on the side of the lesion, a symptom which is only consistent with its usual origin in the sheath of the nerve. On the other hand, in the intra-cerebellar cases, there is rarely any material affection of hearing. In one case of extra-cerebellar cyst, originating, however, in the anterior basal portion of the fossa, the author observed definite nerve deafness which disappeared upon evacuation of the cyst and reappeared with its re-formation. There are in many cases, also, subjective eighth-nerve sensations, especially tinnitus. This is the natural effect of pressure upon the nerve in the extra-cerebellar lesions, while in the intra-cerebellar cases it is but rarely found.

FIG. 82.—Photograph of a Child, aged five Years, Showing Position of Head Assumed in a Lesion of the Right Lateral Lobe of the Cerebellum. (Batten.) "When standing or sitting she held her head to one side, so that her left ear was approximated to the left shoulder; her face was turned to the right, and the chin was slightly elevated; there was a slight spinal curve, with the concavity to the left." (Reproduced from Ballance.) Note that this position, which is also the one seen in the author's patient, is the reverse of that described by Stewart and Holmes as the more usual type.

Involvement of the Facial Nerve.—It is rather peculiar that the seventh nerve, in spite of its intimate connection with the eighth, frequently escapes paralysis from the pressure of lateral-recess growths. If it does appear, it comes late; and then speaks rather for an extra-cerebellar site of the lesion. The same may be said of the fifth nerve, which is occasionally pressed upon, giving rise to pain or to actual loss of sensation. The ninth, tenth, and eleventh nerves are rarely affected, and then usually by lateral-recess tumors only, and late in the disease. The effects are seen in difficulty of articulation and of swallowing.

Eye Symptoms.—The eye symptoms, on the other hand, are rather characteristic. The sixth-nerve palsy (external rectus), frequently present here as in most other intracranial tumors, is often transient and has no diagnostic importance. The pupils are not affected. It is the nuclei concerned with conjugate deviation that are most often involved. The deviation of the eyes to the side opposite the lesion is rather frequent; but deviation toward the side of the lesion, as already mentioned, is rarely seen save in acute and especially post-operative conditions. It is a sign indicative of irritation and rarely lasts long.

Nystagmus.—Nystagmus is one of the classical signs; it is almost invariably present at some stage or other. Its type, as described by Stewart and Holmes and confirmed by Bruns, is a slow, deliberate, and jerking movement to the side of the lesion when the patient looks in that direction, with gradual recession to the middle line. It has some value in the diagnosis of the side on which the lesion is located, for this type of movement, when the patient looks toward the opposite side, is finer and more rapid.

Paresis of the Homolateral Muscles.—Paresis of the homolateral muscles is, again, one of the signs that is most frequently seen in acute and post-operative conditions, and missed in the chronic cases. When present, it is of great diagnostic value in determining the side of the lesion. It affects the trunk muscles most definitely, and this is evidenced in lordosis on standing. It is not due to pressure on the pyramidal tracts, because of the absence of spasticity, the retention of the superficial reflexes, and finally its homolateral situation; but its causation is still unclear. It is rarely found with extra-cerebellar tumors, for these are so situated as rather to cause pressure on the motor fibres in the brain stem, with consequent paralysis of the contra-lateral muscles and other signs of the "crossed hemiplegia" of organic cause.

FIG. 83.—Position of Head in Right Cerebellar Lesion. (Author's Case.) Boy of six. Occiput slightly drawn toward opposite shoulder, and chin turned upward and toward the side of the lesion. This is the reverse of the type-position described by Russell and by Stewart and Holmes, but is recognized as being not infrequent. Compare with Batten's case, Fig. 82.

Muscular Atonia.—Lack of tone in the muscles of the same side as the lesion is particularly emphasized as a reliable sign of an intra-cerebellar newgrowth. If the limb be held at the elbow or knee and then be shaken, the distal portion moves like the limb of a flail. With this, the tendon reflexes are not abolished, rather are they often increased. This again is a symptom not usually seen in chronic cases.

A good deal of emphasis has been laid upon a certain attitude of the head in cerebellar lesions, especially by Risien Russell. The head is said to be slightly flexed toward the side of the lesion, and rotated so that the chin is directed toward the opposite shoulder and the occiput is drawn down toward the point of the homolateral shoulder. The position when present is very characteristic, but is not constant nor pathognomonic. It is occasionally found to be the reverse of the above, as is seen in the accompanying illustration (see Fig. 82), showing a patient of Batten's, and also in a case of the writer's. (See Fig. 83.) In the latter instance the pressure was extra-cerebellar, although the cerebellum itself was compressed to nearly half its normal size. The disappearance of the symptom shortly after relief of the pressure was very striking (see Fig. 84), and its reappearance upon reaccumulation of the original cyst was again remarkable.

Fig. 84.—Patient Shown in Fig. 83, Two Months after Operation. Note the disappearance of the cerebellar attitude of the head.

There are seen at times certain involuntary movements in the shape of tremor; that is, in the absence of attempt at coordinated movement. In the extra-cerebellar cases this is frequently present, and is in striking contrast with the absence of all tremor in the intra-cerebellar cases. In the test the arms are held out horizontally. This symptom is in great contrast with the usual inco-ordination of purposive movement, and, as Stewart and Holmes remark, "the sign emphasizes the purely kinetic character of the ataxia."

Sensory Symptoms.—It is remarkable that, save in the extra-cerebellar cases in which the fifth nerve may be affected by direct pressure, there is never loss of cutaneous sensibility, nor of the sense of position of the limbs, nor of stereognosis, unless the pons be very markedly compressed.

The mental condition of the patient is rarely affected, save by his headache and by the general compression of the late stages. The reflexes are very variable. They may be increased, diminished, or normal, and may vary from day to day. An increase of the knee jerk speaks for an extra-cerebellar growth which presses upon the pyramidal tract. If the mind is affected and if the reflexes are increased it is probable that hydrocephalus has entered as a complication. The same remarks are applicable to the Babinski toe phenomenon.

The tendency to abduction of the homolateral leg has been observed both in experiments and clinically. (See Fig. 85.) In the case represented in the appended illustration (see Fig. 86) this abduction proved to be still another misleading sign in the differential diagnosis between a cerebellar and a frontal tumor. A cerebellar growth was diagnosed in this patient, and autopsy showed the tumor to be in the opposite frontal lobe. (See Fig. 77.)

Diagnosis.—The diagnosis of a growth in the posterior fossa is not usually difficult, but the differentiation of one situated in the cerebellar substance proper from one that lies in the brain stem, the corpora quadrigemina, the pons, the medulla, or one of the peduncles, is frequently difficult. We have already indicated the main points of difference between the cerebello-pontine-angle growths and the intra-cerebellar ones.

Any confusion that arises is chiefly due to the presence of focal cerebellar signs (ataxia, vertigo, etc.) from pressure on the cerebellum exercised

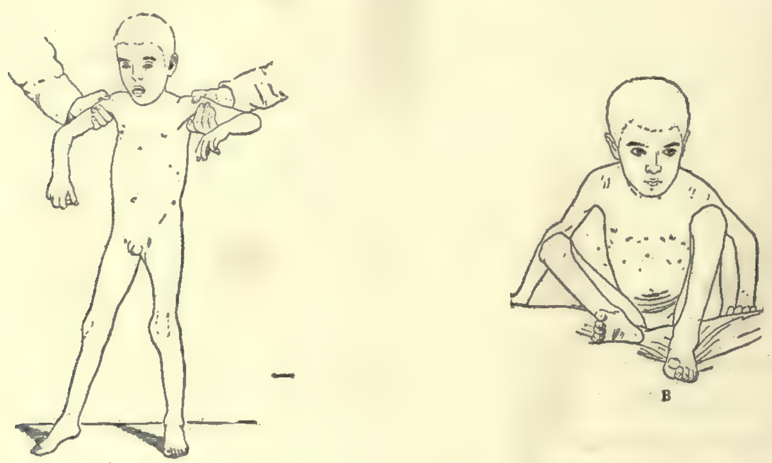

Fig. 85.—Child with Right Cerebellar Tumor (Solitary Tubercle). (Louis Tollemer, in the Charcot-Bouchard-Brissaud "Traité de Médecine," 2d ed., vol. ix. Reproduced from Ballance, *loc. cit.*, p. 235.) Note that, because of disturbance of equilibrium, the feet, in the standing position, are widely separated, the abduction being greatest on the side of the lesion. *A*, Position when standing, right thigh abducted; *B*, position when sitting, right thigh abducted.

by growths outside of it. The most important point in differentiation is to be found in the time of appearance of these symptoms. In the intra-cerebellar cases they appear early and are marked; in bulbar or pontine tumors they appear late, and are frequently preceded by symptoms of pressure on the cranial nerves, expecially the seventh and eighth, less often the ninth, tenth, and eleventh.

For instance, in the patient whose brain is represented in Fig. 81 there appeared a paralysis of the right eighth nerve with loss of hearing two years before the appearance of other symptoms, and three years before admission to the hospital. Nearly one year before his death there appeared some palsy of the seventh nerve too; then, shortly afterward, weakness in both legs, and, finally, three months before admission, disturbance of speech, probably from paralysis of the palatal muscles. It was only shortly before admission that cerebellar ataxia developed. There were also present the signs of pressure on the crura, seen in increased knee jerks and in the extensor response of the big toe. With all this there were present headache, vomiting, and optic neuritis. At the post-mortem examination the growth, as seen in the illustration, was loosely adherent to the dura mater and the sheath of the eighth nerve which it had compressed to the point of obliteration. It had also compressed the right half of the cerebellum and caused extensive atrophy of the pons, so that the right half of the latter was only one-third the size of the left half. The upper end of the medulla was also somewhat atrophied. It was a fibroma, and there was no other evidence of new growth.

FIG. 86.—Abduction Position of the Leg Suggestive of Cerebellar Localization in a Case of Frontal Tumor. (Case of Drs. Martin and Russell, Royal Victoria Hospital.)

Another case seen by the writer is illustrated in Fig. 69. Here the growth, a glioma, had begun, apparently, in the floor of the fourth ventricle and had compressed the anterior portion of the middle lobe of the cerebellum and the aqueduct of Sylvius, with the consequent production of considerable hydrocephalus. Symptoms of generalized compression became rapidly severe a few days before death. In this instance, too, the ataxia and vertigo had appeared somewhat late in the disease. The patient had had the general signs of intracranial tumor for six years, though of mild grade, and practically stationary. The symptoms were those of general compression, probably from the complicating hydrocephalus; the situation of the tumor in the medulla seemed to yield no focal signs till late, and then they were of cerebellar type. Operation undertaken in the cerebellar region for decompression, during the paralytic stage, resulted only in giving exit to an uncontrollable hernia, without relief.

Tumors of the Pituitary Body and Region of the Sella Turcica.—It is still a matter for discussion to what extent the tumors of the hypophysis are associated in a causal way with acromegaly. It seems clear that while a number of such tumors do show this association, the exceptions are by no means rare.* Speaking generally, the true neoplasms of the hypophysis often cause rapid and atypical dystrophies of various nature, such as acute acromegaly, rapid cachexia simulating Addison's disease without symptoms of acromegaly; œdema of the face and limbs, suggesting myxœdema; gigantism; sexual infantilism with loss of the hair over the body generally; and finally the painful forms of acromegaly.† Nat-

* See Cagnetto, in Virchow's Archiv, Bd. clxxxvii., Heft 2, 1907; also Lewis, in Trans. of the Chicago Path. Soc., vol. xi., No. 7, p. 230.

† See Goetze und Erdheim: "Zur Casuistik der trophischen Stoerungen bei Hirntumoren," Wien, 1906.

urally: there will be also the symptoms dependent upon compression of neighboring nerves. The optic nerves are apt to suffer chiefly, and the situation of the pituitary in the anterior angle of the chiasm causes frequently, as a symptom, a bitemporal hemianopsia. In addition, the third, fourth, sixth, and fifth nerves are apt to be paralyzed, giving rise to squint, ptosis, and in fact a more or less complete ophthalmoplegia. The anatomical relations which make these signs comprehensible are well seen in Plate XXXIV, Fig. 1. These lesions lead naturally to rather early blindness. With all this goes ordinarily a total

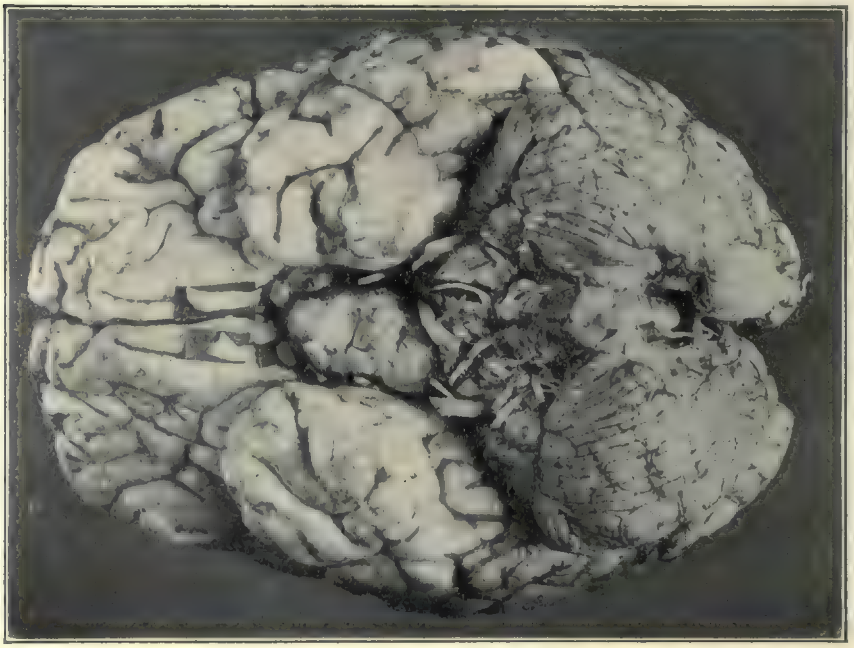

Fig. 87.—Endothelioma of Dura, Compressing Pituitary Body, Optic Chiasm, and Right Crus. There was descending degeneration in the crossed pyramidal tract of both sides. Clinically, there was a history of eight months of symptoms, beginning with headache and loss of vision. Mental state became poor; marked loss of memory, optic neuritis, and paresis of left leg developed. Until just before death there were no ocular palsies nor nystagmus. Pupils were equal and active; no definite hemianopsia discovered or, at any rate, mentioned. Smell and taste remained normal. (Path. Dept., Royal Victoria Hosp., 24, 1901.)

lack of motor or sensory disturbance in face, trunk, or limbs. The illustrations (Figs. 87 and 88) are instructive, although the history of the case is somewhat defective. Here the tumor arose, not in the pituitary gland, but from the dura, and was an endothelioma. The lack of symptoms referable to disturbance of the pituitary secretion (dystrophies, etc.) was noticeable; while in another instance (Royal Victoria Hospital, Pathological Department, No. 2, 1899), a true pituitary tumor in this case, there existed one of the various dystrophies already mentioned, to which Cushing has lately called particular attention, namely, that of sexual infantilism.

These tumors in their growth frequently enlarge the sella turcica very materially, as Oppenheim first showed, so that a good skiagram may often be of decided help. Indeed, this is perhaps the only place in which the x-rays are of service in the diagnosis of cerebral tumors.

Tumors of the Basal Surface.—These tumors usually give signs referable to the cranial nerves chiefly. They arise ordinarily from the dura mater (endotheliomata) or from the bone (sarcoma). Fig. 89 illustrates an endothelioma in the middle fossa, extirpated by Ali Krogius in 1895, and interesting as being

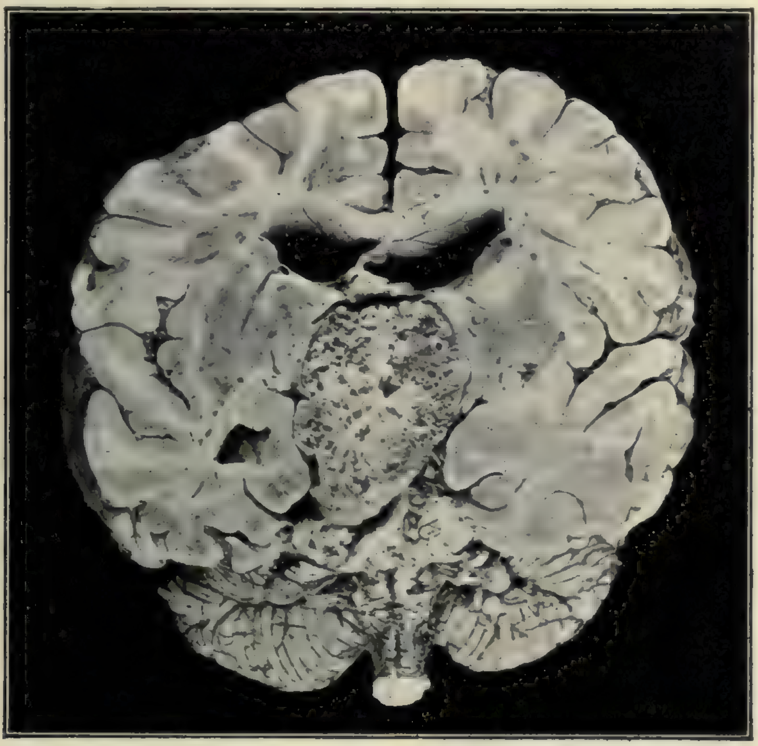

FIG. 88.—Coronal and Slightly Oblique Section through Tumor Shown in Fig. 87. Note its extension from base up to lateral ventricles, practically obliterating the third ventricle, and causing moderate hydrocephalus. (Path. Dept., Royal Victoria Hospital, 24, 1901.)

the first reported tumor of this region to be attacked surgically. Its beginning and course were characterized by trigeminal neuralgia; later, anæsthesia, together with third and sixth nerve palsy, appeared. Such are the ordinary signs of growths in the middle fossa; and trigeminal neuralgia is particularly frequent. Sarcomata often grow upward from the upper jaw, or the sphenoid, or the naso-pharynx; and their invasion of the middle fossa is signalled by pain in the distribution of the fifth nerve.

Tumors of the Basal Ganglia.—Tumors of the basal ganglia show themselves chiefly by compression of the motor and sensory paths in the internal capsule or crura. The lesions of the *corpora quadrigemina* may simulate almost exactly those of the cerebellum. Growths in the *corpus callosum*, obstructing, as they do, a vast system of commissural fibres, may cause bilateral disturbances of motility, of sensation, and of vision. If situated anteriorly they are particularly apt to cause psychical deterioration and simulate pre-frontal tumors. In all these instances the place of surgery lies only in the direction of palliation.

Prognosis of Cerebral Neoplasms.—It is hardly necessary to say that the course of a cerebral tumor left to itself is uniformly toward death. Those rare exceptions of spontaneous retrogression by degeneration, even of large tumors, to which Sir Victor Horsley has called attention, are, indeed, rare exceptions, and serve only to prove the rule. Tuberculomata may occasionally, as in other parts of the body, become quiescent, or even undergo cure by calcification, but this too is rare.

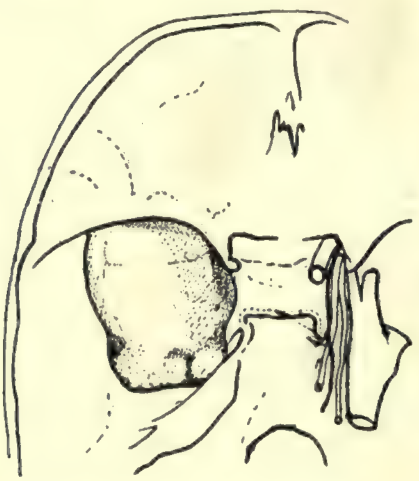

Fig. 89.—Endothelioma of the Base, in the Left Middle Fossa, Removed by Ali Krogius (Helsingfors) in 1895. Death on the thirteenth day from meningitis. (First attempt to remove a tumor in this situation.) (Heiberg in Chipault, "État Actuel," etc., vol. ii., p. 12.)

And this inevitable death is often a lingering one, ending an existence which has been rendered inexpressibly miserable by pain and blindness. The ordinary sedatives are frequently insufficient, and the temptation to help the patient to euthanasia is often great.

Treatment of Cerebral Tumors.—There is perhaps no field of therapeutics in which surgical intervention has a more legitimate place. And this by reason of the nature of the malady rather than, one must confess, from the brilliancy or certainty of its results. "Dubia spes certa desperatione potior," said Celsus; and surely nowhere is despair more certain, even if nowhere, as some say, is hope more doubtful. Operation finds its justification primarily in the fatality of the disease; yet the lapse of time is also giving it a "justification by works." The possibilities of curative medical treatment are ended with the success or failure of a course of antisyphilitic treatment; and those of palliative treatment are soon narrowed to the resigned adoption by patient and physician of morphia as a matter of regular régime. Under such circumstances it becomes natural to inquire what prospect, if any, is held out by surgery. And the surgery of cerebral tumors at the present day is based upon two principles: the one to effect cure by removal of the tumor; the other to afford relief of symptoms by the relief of intracranial tension.

Radical Operations.—Of general statistics the collection of Duret is the largest at present available, and consists of 400 cases of operation. As to site, 244, or 61 per cent, were situated in the motor region. Duret, however, includes all cases of tumor in the post-frontal lobe in the motor class, reserving the term frontal for the pre-frontal area. In the latter there were 54 cases, or 13.5 per cent; in the parietal 10, in the occipital 15; in the temporal 12 cases; and in the cerebellar 59, or 14.75 per cent. With recent advances in diagnosis of situation and in technique, such proportions will probably be altered materially in favor of the extra-Rolandic territory.

From the beginning of this branch of surgery, those tumors which are situated in the motor cortex have been the most frequently and most easily removed. They are, in fact, those which are most susceptible of early diagnosis and most easy of access. Of 183 cases in Duret's table, 116 recovered from the operation without being further traced; 26 remained cured for a year, 18 for a period of from 1 to 2 years; 14 for from 2 to 3 years, and 9 for over 3 years; 21 were improved, and 12 showed no improvement. These are the tumors which give the most definite indications for surgical removal. But lately the advances in the science of diagnosis have widened the field of surgical interference and have fortunately been supported by a corresponding advance in technique. There are many more growths considered operable to-day than there were even five years ago. These are chiefly those of the occipital, cerebellar, and basal regions. Horsley's astonishing series of eleven operations for the removal of tumors of the hypophysis furnishes the most striking evidence of this. How many of these lived he does not say; but the writer was fortunate enough to have the opportunity, in 1906, of examining one of them some ten months after operation. The man was in excellent general condition, was freed from his headache and other cranial-nerve symptoms, and suffered only from a moderate grade of neurasthenia. Acromegaly, in this patient, had not been clearly present, although a slight general thickening of the skin remotely suggested it.

Much has been written during the last few years concerning the best way of approaching the pituitary growths, and mainly upon the basis of cadaver operations. Krause, Schloffer, von Eiselsberg, Kiliani, Hartley, Braun have proposed various types of operation—through the nares and sphenoid, from the frontal aspect, from both sides over the frontal lobes, and through the middle fossa.

Horsley operates through a large opening in the temporal region, displacing the temporal lobe upward. Schloffer, von Eiselsberg, and Hochenegg have each operated on one case of pituitary growth; in all cases access was gained by the nasal route, going through the body of the sphenoid.

Schloffer's patient was greatly relieved for two or three months, but then died rather suddenly, and at the post-mortem examination it was found that only a small part of the tumor had been removed at the operation. Such must often be the case, one would think, with the exceedingly limited access possible. Hochenegg's patient was affected with marked acromegaly; the pituitary was much enlarged and was removed by curetting. Prompt and decided improvement followed.

In the occipital region Oppenheim and Krause report lately a case of successful removal of a tumor that was of large size.

In the region of the cerebello-pontine angle, at the anterior pole of the posterior fossa, a situation which was not long ago considered quite inaccessible, the removal of fibromata from the sheath of the eighth nerve is becoming almost an ordinary affair. The results, which should be excellent with such a benign form of growth, are spoiled by the difficulty of proper access and by the deaths that result from complications inherent in the difficulty of the operation. In Horsley's series (Stewart and Holmes) of 9 cases of extra-cerebellar growths operated on, 6 died and 3 recovered. Of the deaths 2 were due to post-operative infection, 1 to secondary hemorrhage, 1 to pneumonia, and 2 died, probably of compression, after the first stage. Borchhardt has lately published an exhaustive article upon operations in the posterior fossa, including a review of 152 published cases. This in some measure supplants Frazier's valuable statistics published two years ago. Of 19 cases of tumor in this region 4 were cured, 1 improved, and 14 died. The technical difficulties are so great and the situation of the growth, pressing as it does on the medulla and pons, so dangerous for the necessary manipulations of removal that the results must probably always remain poor.

The results are better on the whole when the lesion lies in the cerebellum proper, except where the vermis is affected, when practically all the patients die sooner or later. Borchhardt's table again is valuable. In 13 cases of true cysts operated upon there were 13 recoveries—a surgical triumph. The reverse of the medal appears in the figures of the tuberculomata. Of 21 of these 12 died from shock, 3 of meningitis within two or three months, 3 of tuberculosis in some other part of the body within nine months, and 1 recovered and was well thirteen months after operation.

Of Borchhardt's 101 cases of true tumor (glioma, sarcoma, fibro-sarcoma) there were 60 in which the tumor was not found at all at the time of the operation, and 60 died soon after operation. But 17 were cured, 15 improved, and in 15 much relief was got by decompression without removal. Such results, in view of the seriousness of the condition, are encouraging. In estimating them it is evident that the proportion of successes must suffer from the lack of experience of the general surgeon in this branch of special work; on the other hand, an exaggeration of the benefit doubtless accrues from the natural tendency of man to publish only, or chiefly, his good results.

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Oppenheim and Krause, in Berl. klin. Woch., Dec. 17th, 1906.
Borchhardt, in Arch. f. klin. Chir., Bd. lxxxi.
See also Woolsey, in Trans. Amer. Surg. Soc., 1903.

Causes of Death after Operation.—According to Duret early death resulted from shock in 58 cases, 14 per cent; in 10 from hyperthermia, and in 10 from hemorrhage; making a total of 19.5 per cent of operative mortality. In the majority of these cases the size of the growth was very large, or it was not found at all.

Shock is caused, according to Horsley, more by the removal of bone than by the manipulations of the brain, if the latter are conducted with proper care; but in the latter case, too, there are special considerations which particularly influence the production of shock, and of these the chief is perhaps dependent upon accurate diagnosis of the seat of the lesion. Thus, if the diagnosis has been mistaken and the opening has relieved only partly the existing compression, shock is certainly greater than otherwise. In Horsley's table there were 13 patients who died of shock after the second stage. Of this number there were 7 whose death might be attributed to failure of diagnosis of the site, so that the tumor was not found at operation; whereas of the remaining 6 patients, in whose cases the tumor was directly exposed but no removal was attempted, owing to the size of the growth and for other reasons, not one died from this cause. Again, of 79 patients in whose cases a correct diagnosis was made and the tumor successfully removed, 7 died of shock; whereas in 16 in whom the condition was incorrectly diagnosed and in whom, consequently, no tumor was removed, 6 died from shock. In the first group, therefore, the deaths from shock amounted to only 8 per cent, while in the other it amounted to 37 per cent.

There is another point of view. The danger of the operation varies very definitely with the region attacked. The motor area is especially favorable in this regard. In Horsley's table there was but 1 death from shock in 27 operations in this field; in the parietal and post-parietal regions, there was 1 in 19; in the frontal region, 1 in 13; in the temporal, 1 in 12; and in the cerebellar region, 1 in 10. Duret found 24 early deaths in 59 operations on the cerebellum. The difference between the statistics of the expert and those of general literature as regards operations on the cerebellum is noteworthy. Apart from what has been said, the causes of lack of success, upon analysis, appear to lie in the great size of the tumor, in erroneous diagnosis of its situation, or in incomplete extirpation.

Improvement and Cure.—Duret found in his 400 cases 258 that were either cured or notably and permanently improved. In 35 others improvement was slight, and in 18 it was nil. Of the cases traced, the cure had lasted over three years in 20. Duret calculates that 73 per cent received some benefit from the operation.

Apart from the purely technical considerations and the differences due to the region in which the operation is carried out, the chief factor in the end results consists in the nature of the growth. Of the fatal cases in Duret's table, two-thirds were gliomata and sarcomata. In this respect we may quote also Horsley's table of 55 tumors: In 23 cases, 19 of glioma and 4 of sarcoma, successfully removed, recurrence appeared in 20 within two years; in 8 cases of endothelioma there was but 1 recurrence—7 were alive and well for some time afterward, one of them even five years afterward; of 4 patients affected with tuberculoma 2 died within three months of tuberculous meningitis, and 2 were still alive and well—1 as long as seven years afterward; out of 8 cases of gumma there was not a single instance of recurrence; and the same statement is true of 4 cases of fibroma and 5 of cyst. Of 3 adenomata of the pituitary body recurrence appeared in 1.

Of 13 patients operated on for cyst of the cerebellum, all, according to the statistics of Borchhardt, recovered.

Such statistics form the best justification possible for the legitimacy of the operation for cerebral tumor. The one dark point in the picture is the frequency with which gliomata occur. These infiltrating malignant growths often spread through the nerve tissue for a long time before they cause definite symptoms, so that their size is apt to be already great before diagnosis can be made and operation attempted, so great often as to render them inoperable. On the other hand, in the case of the encapsulated tumors—fibromata, endotheliomata, and gummata,—which affect nerve tissue chiefly by pressure, the result is often brilliant; the various paralyses show themselves to be merely pressure paralyses, and often complete restoration of function is obtained.

The Palliative Operation.—Horsley in 1890 was the first to call attention to the beneficial effect of the removal of bone in relieving symptoms due to compression. He mentioned in particular the disappearance of headache, of fits, and of optic neuritis, the recovery of sight, and the prolongation of life. From 1885 to 1890 he had done six operations of this character. Sahli then proposed operating over a silent region to avoid the ill effects of hernia in functionally important areas; and the French gave the name of "decompressive" to the procedure. Paul, in 1894, operating for Caton in the case of a hypophyseal tumor with acromegaly, chose the right temporal region and did not open the dura mater; the result obtained was excellent. Since then the right parietal lobe has frequently been chosen as a silent region and is recommended by Saenger; but lately Cushing has called attention to the advantages of a muscular covering, and has devised a split-muscle operation in the temporal region; this is rapidly becoming the method of choice. The writer, in common with many others, has found it of great advantage. If care be taken to keep below the superior temporal convolution,—that is, below the word-hearing centre,—one need not hesitate to operate on the left side. But, if a bilateral operation is done, the dura had best be left intact on the left side. The decompressive operation is not difficult nor materially dangerous, provided due precautions are taken to secure asepsis. It often brings enormous relief. It is necessary, however, that a thorough neurological examination should first pronounce the underlying condition to be an unlocalizable tumor. Otherwise the patient may be robbed of his chance of a radical removal of the growth.

The indications for the decompressive operation are persistent severe headache, vomiting, and optic neuritis, with threatening blindness. The testimony of many goes strongly to show that the relief of pain and the preservation of sight—two of the most important things in the physical life of a man—are as a rule obtained. The article of Spiller and Frazier published two years ago, and that of Saenger last year,—not to mention many sporadic reports scattered through the literature,—prove this with welcome certainty. Of Saenger's 19 cases there were 16 in which the decompressive operation proved beneficial, and 2 in which it produced no effect; in 1 the symptoms were made worse. Of Spiller and Frazier's 14 cases all but 1 obtained great relief. The mortality is *nil* in these later reports.

References.

The vast bibliography of this subject is to be found in such recent works as the following:

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Saenger, in Verhandl. d. Deut. Gesellsch. f. Chir., vol. xxxi., 1903, p. 158; also, in klin. Monatsbl. f. Augenheilkunde, 1907, Bd. xlv.

Cushing, in Surgery, Gynæcology, and Obstetrics, Oct., 1905.

Spiller and Frazier, in Univ. Penn. Med. Bull., Sept., 1906.

Rohmer et Dupont: Thèse de Nancy, 1908.

One thing is apt to defeat the object of decompression—hydrocephalus. Here the extra space afforded is made of no avail, for the cerebro-spinal fluid may claim it without giving any *quid pro quo*. Thus the tumors of the brain stem and cerebellum, which so frequently block the fourth ventricle or the iter, are apt to benefit little from the operation. Fortunately, however, at times the relief of pressure is sufficient to reopen the obstructed ventricular exits and give relief to the hydrocephalus itself. Here, inasmuch as the growth often gives cerebellar signs, operation is first undertaken as a possibly radical one, and, nothing being found save great tension, is ended as a decompressive one.

XXII. THE TECHNIQUE OF CEREBRAL OPERATIONS.

There is perhaps no department of surgery which is so difficult and at the same time so thankless as is that of the brain. The early enthusiasm of a short generation back has given place to more sober conceptions based upon the accumulation of late results and of large statistics. One realizes now that radical cures, at least as regards the tumors, are rarely to be expected. And the cause lies not alone in the frequent difficulty of accurate localization, although our knowledge in this direction is constantly growing, nor in the difficulty of access to many of the tumors which one is able to localize, but also in the actual danger to life which is involved in operations for conditions which affect very seriously the fundamental centres of life. There must be added such considerations as the particular liability of the leptomeninges to infection, and the difficulty of controlling hemorrhage in the soft brain substance; also the danger of shock from extensive interference with sensory nerves involved in making any wide opening in the skull. The diagnosis may be brilliant, but the least flaw of asepsis—a flaw that might do no harm in the peritoneum—is here sufficient to render the operation futile and cost the patient his life from meningitis. Or a lack of acquaintance with the proper methods of controlling bleeding from the extremely delicate vessels of the pia and the quite unsupported ones in the cerebral tissue, may be followed by disastrous results from the one factor of hemorrhage;—not, perhaps, from the amount of blood lost, but from the compression exerted by the retained blood upon the medullary centres.

When one analyzes, therefore, the prime necessities of technique in this department of surgery, one finds that they concern chiefly the avoidance of certain particular dangers. First, the danger of infection; then that of shock from loss of blood; then the danger of compression from retained blood; and finally that which arises from all those factors which have a direct bearing upon the bulbar centres, and which necessitate fundamental physiological knowledge. These concern the effect of anæsthetics; the hydrostatic and hydrodynamic effect of position of the body; the action of various drugs, especially the general class of stimulants; the effect of anæmia, whether primary or from loss of blood; the maintenance of body heat; and many others. All these points must now be considered separately.

First, the question of infection. The scalp with its abundant supply of hair and of sebaceous glands has long been considered a factor of danger in respect of infection. And therefore, since the days when one began to use the Lister method, the pre-operative cleansing of the scalp has occupied the attention of surgeons very closely. The conspicuous success of such men as Horsley, Krause, Harvey Cushing, Frazier, and certain others can be ascribed very materially to their care in this matter.* Horsley lays down the rule that the scalp should be shaved if possible at least two days before the operation, and should be cleansed twice with cloths soaked in sublimate or carbolic-acid solution, after the usual scrubbing. Ethereal soap and scrubbing with ether and alcohol have been recommended in order to get rid of the fat on the surface. Whether such a prolonged preparation is necessary must be considered doubtful in the light of Harvey Cushing's record of over three hundred and fifty operations without the least infection. He prefers to shave and wash the head immediately before operation, before the anæsthetic is given. This is followed by scrubbing with bichloride and alcohol, 1 in 1,000; the idea being that prolonged moist dressings are only apt to produce maceration of the epidermis with the production of minute staphylococcus abscesses. The writer recalls an article from the late von Bergmann's Polyclinic which, on the basis of experimental work, went to demonstrate the truth of this statement. In the way of antiseptics the writer has lately employed on several occasions the benzene-iodine preparation of Heusner, and has so far found it reliable. It avoids the splashing of soap and water, and the liability of soap getting into the eyes of the patient through carelessness.

FIG. 90.—Gauze Cap with Tourniquet Applied before Inflation. (From Cushing: "Pneumatic Tourniquets," *Medical News*, March 26th, 1904.)

Although Cushing no longer uses an inflatable tourniquet, the illustration is reproduced in order to show the position in which any tourniquet should be applied and also the device of the gauze cap which serves to protect the area of operation from the rest of the scalp.

The scalp having been properly cleansed in one of these ways, it is necessary to keep covered all but the immediate area of operation, in order that hands and instruments may not come into contact with the bare skin of the rest of the head, the asepsis of which, in spite of all precautions, must always be doubtful. This is best accomplished by covering the head with a large fold of

* Horsley: "On the Technique of Operations on the Central Nervous System." Brit. Med. Jour., Aug. 23d, 1906.—Krause, in Arch. f. klin. Chir., Bd. lxxxi., Th. 1; also article on "Hirnchirurgie" in Die Deutsche Klinik, 1903.—Harvey Cushing: "The Technique of Cranial Operations." Surgery, Gynæcology, and Obstetrics, May, 1908.—C. H. Frazier: "Remarks upon the Surgical Aspects of Tumors of the Cerebellum." N. Y. Med. Jour., 1905, p. 278; also, "Remarks upon the Surgical Aspects of Tumors of the Cerebrum." Univ. Penn. Med. Bull., April–May, 1906.—See also on the subject of technique: Hartley and Kenyon, in Annals of Surgery, April, 1907. Borchhardt, in Centralbl. f. Chir., Bd. xxxiii., No. 38.—W. W. Keen, in Buck's "Reference Handbook of the Medical Sciences," 2d ed., article on Brain Surgery.—Kocher: "Hirnerschütterung, Hirndruck und Hirnchirurgische Operationen." Nothnagel, Bd. ix., Abth. iii., Th. 2.

sterilized cheese-cloth. (See Fig. 90.) Incision of the scalp may be made directly through this. It is the writer's practice to paint the skin with pure tincture of iodine in the field of operation after completing the ordinary process of sterilization. When the flap of soft parts is turned back, with or without the bone, it should be wrapped in a fold of wet bichloride gauze. Once the dura has been opened, it is well, after Horsley's fashion, to irrigate the surface at frequent intervals during the operation on the brain. For this purpose he uses a bichloride solution, 1 in 10,000.

When the operation is finished and the flap has been replaced, there arises the question of *drainage*. For the thorough avoidance of infection, it is essential that the wound be entirely closed without drainage. A drain, even for no more than a day or two, is always the weak link. It gives an avenue for the entrance of infection from the skin along its track. There are perhaps few surgeons who have not, in an aseptic operation, seen meningitis develop, which could be reasonably traced to the presence of a drain. As for the objection that it is necessary to provide for the escape of effused blood, one must answer that a drainage tube usually fails in any case to do this. Clotting prevents it. On the other hand, apart from blood, there is very rarely any need for the removal of reactionary serous exudation or cerebro-spinal fluid. If these form in excess they will pass out into the subcutaneous tissue underneath the closed scalp and will, as I have frequently observed, be absorbed from this situation with perfect ease. Such subcutaneous auto-drainage is far preferable to external drainage. There is another reason for the avoidance of even a twenty-four-hour drain, and that is the opportunity which it affords for the persistent escape of cerebro-spinal fluid. If the latter is under any tension it is very apt to force its way through the weak spot which is afforded by even a small cigarette drain; and, with persistent escape of cerebro-spinal fluid, one is very apt to find high fever. This was a matter of common observation at Queen's Square, and the fever was found to disappear as soon as the wound became sufficiently closed to prevent further loss of cerebro-spinal fluid. If such a sinus does persist, giving exit to large quantities of cerebro-spinal fluid, it is difficult to close it secondarily without more or less of an operation. On the other hand, the pressure exercised by such reactionary effusion is not serious, not, at least, sufficiently so to justify routine drainage. Careful and frequent blood-pressure observations should in all cases be taken after operation, and if there occur any material retention of blood or of serous exudate, the changes in blood pressure, respiration, and pulse will give plenty of warning. The avoidance, therefore, of drainage is perhaps the most important single measure that we possess for the prevention of infection.

The wound being closed and dressed, it is well to put on over the dressing a rubber or oiled-silk bib, which surrounds the face in an oval, and is bandaged close to the skin. This is to prevent the soiling of the dressings by vomited matter. It is of routine employment in Horsley's service at the Queen's Square Hospital. One other point is important. If the operation is to be done in two stages, the skin stitches of the first stage should be removed on the second or third day, as advised by Cushing. The scalp will rarely suffer the presence of sutures for more than a few days without developing stitch infections, no matter how well it be primarily disinfected. It seems probable to the writer that Cushing's unbroken record of clean wounds is due more to this early removal of sutures than to the mode of "washing up."

Prevention of Shock.—The maintenance of the body temperature is a matter of prime importance. The operating-room should be warm, and the patient should be well wrapped up. Such measures as these keep up the general body heat of the patient. Horsley, however, is firmly convinced that it is even more necessary to maintain the normal conditions of heat and moisture in the area of operation. For this purpose he uses more or less constantly throughout the operation an irrigation of weak bichloride solution (1 in 10,000) which, in the irrigating-can, is kept at 115° F. Hot irrigation is also used by Horsley for its hæmostatic effect on capillary and arteriolar bleeding from the cerebral substance. The writer believes that such irrigation does not accomplish much in hæmostasis. In any case if a vessel of any size is bleeding, the water obscures the field and prevents early recognition of the fact. Irrigation, therefore, is used by the writer only in so far as it keeps up local heat and moisture; that is, it is used at intervals throughout the operation, but hæmostasis is secured by other means. This brings us to the question of hemorrhage.

Control of Hemorrhage.—In the first place, while a certain loss of blood is well borne by a patient in good general condition, it must be remembered that even a small loss is acutely felt by a patient who is in the acme stage of cerebral compression. Here anything that lowers blood pressure may increase the bulbar anæmia already present and cause vasomotor paralysis. I have verified this by blood-pressure records. I regard the tourniquet (see Fig. 90), as used by Cushing and many others, as of great advantage in the ordinary case, in which compensation for cerebral compression may be perfect, but of doubtful value where the compression is severe. Under these latter conditions the venous blood is having a hard task to get from the cranium to the heart, and is passing to a considerable degree through the emissary veins by the roundabout way of the scalp. The tourniquet blocks this avenue of escape, and, I think, is apt to promote bleeding, if it do not increase intra-cerebral compression by adding to the already severe condition of venous stagnation. In such cases, therefore, the aim should be to confine the hæmostasis to the area of operation. The ordinary artery forceps here acts slowly and is insufficient. It is better to use a forceps with a wide grip like Howzell's, a few of which will compress the whole extent of the cut edges. Both time and blood are saved in this way.

Various other procedures have been devised for the control of scalp hemorrhage. Heidenhain* recommends using subcutaneous mass ligatures interlocked all around the proposed incision; and Krause approves of this method. Kredel† employs a modification of this method, in that his mass ligatures are tied, not upon the skin, but upon a flat metal plate, through perforations in which the ends of the suture are passed. These methods are certainly effectual in giving a fairly bloodless field. The disadvantage, however, lies in not providing for easy extension of the field of operation, and in requiring some expenditure of time. Horsley during the incision compresses the edges with the fingers or hands, until a sufficient number of the ordinary artery forceps can be applied. Hemorrhage from the bone is best controlled by Horsley's wax.‡ While this serves very well for the general oozing from the diploë it is hardly sufficient for the blocking of the larger emissary veins. For these, small wedges of aseptic wood, catgut, or kangaroo tendon of various sizes are satisfactory. If these are not available, the writer has found that absorbent cotton forced in is efficient. This is one of our best hæmostatics for surface oozing and also for the control of bleeding from the cerebral substance itself. Compression, by forceps, of the border of the bone will often quickly and completely arrest the bleeding from this source.

The Administration of an Anæsthetic.—As to the relative advantages of ether and chloroform, there has been much argument. In England, chloroform is generally used; in America, ether; but really it does not seem to make much difference which is chosen, if only it be given by a skilled anæsthetist. Under such circumstances the disadvantages of both anæsthetics are minimized. Horsley says, however, that ether is objectionable because it causes a rise in blood pressure, an increase in the venosity of the blood, and therefore additional and embarrassing hemorrhage; because it stimulates the secretion of mucus and thus embarrasses respiration; and, finally, because it causes in the post-operative period more excitement, vomiting, and headache than does chloroform. He admits that the latter is a more dangerous drug because of its tendency to paralyze the respiratory centre; yet he believes that this is obviated by a scientific administration. With the Vernon-Harcourt apparatus he is able to regulate the dosage of the drug; and the necessary dosage is so low that the danger from this side is extraordinarily diminished. Combined with the Vernon-Harcourt apparatus he uses a tank of oxygen which may be turned in at any moment. We reproduce here Horsley's illustration of this apparatus (Fig. 91) and the manner in which the anæsthetist manages it. The writer can certainly testify to the ease and smoothness of the narcosis under such conditions.

* Heidenhain, in Centralbl. f. Chir., 1904, No. 9.

† Kredel, in Centralbl. f. Chir., Bd. xxxiii., 1906, p. 1137.

‡ The formula of Horsley's wax is: Beeswax, 7 parts; almond oil, 1 part; and salicylic acid, 1 part.

Investigations of a research committee of the British Medical Association showed that a mixture of two per cent of choloroform in the inspired air was sufficient to cause deep narcosis, and the Vernon-Harcourt apparatus is so arranged as not to permit any higher percentage in the respired air than this. It is, moreover, quite unnecessary to keep up this dosage throughout the operation; and in this connection the diagram of Horsley indicating graphically the amount of chloroform necessary at various stages is instructive. (Fig. 92.)

FIG. 91.—Arrangement, at the National Hospital, Queen Square, for Anæsthetization and Oxygenation of the Patient. The Vernon Harcourt regulator is fixed on the conical stand, the chloroform bottle being in a water-bath. The oxygen supply from the horizontal cylinder is readily regulated by the anæsthetist, Dr. Powell. Prof. Theodor Kocher of Berne, who happened to be visiting the hospital at the time, stands at the right of the photograph. (From Sir Victor Horsley's Address at the Toronto Meeting of the British Medical Association, 1906, on "The Technique of Operations on the Central Nervous System.")

Certainly when chloroform is used with such precautions and in such a scientific way as this, objections to it disappear very largely; and in the Royal Victoria Hospital it is not infrequently employed. However, Cushing, Frazier, and others in America employ ether and find it essentially satisfactory. The choice lies between chloroform administered through the Vernon-Harcourt apparatus or some similar one, and ether given by an expert. The choice, I think, should be made according to the degree of intracranial tension present in any given patient, as evidenced by the work of the respiratory and vasomotor centres. Where compression is high and the centres just named give evidence of being overworked, where the respiration is irregular or periodic and blood pressure is at all high, then ether is the better anæsthetic. At such a stage any lowering of the blood pressure might be sufficient to determine the overthrow of these centres, and induce respiratory failure. Chloroform may do that at the best of times. On the other hand, in the same conditions, ether, by virtue of raising blood pressure, has a really marvellous effect, as I have observed on several occasions. Breathing, which was Cheyne-Stokes in type before ether was administered, becomes regular, and a slow pulse rises to normal or above it.

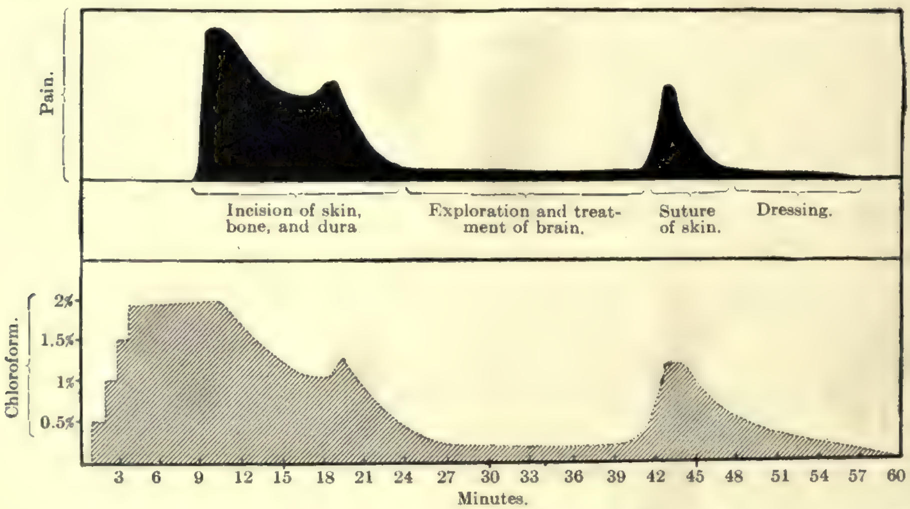

FIG. 92.—Dosage of Chloroform Requisite during Operation. In this diagram the upper curve is that of degrees of pain, the lower that of corresponding percentages of chloroform requisite. The lengths 3 to 60, on the abscissa line, signifies an hour divided into periods of three minutes. The diagram shows in a graphic form that to the stages of induction nominally is given about nine minutes; that after the patient has inhaled 2 per cent vapor for about six minutes he is ready for the operator. The maximum pain being caused by the skin cut, the concentration is lowered for the division of the less sensitive bone, and again raised for the division of the dura. Then, the exploration of the brain being a painless procedure, as the chart shows, a great reduction of the chloroform is made—that is, to 0.3 per cent, or zero. Finally, the dose is raised to meet the pain of skin suture and prevent vomiting. (Horsley, *loc. cit.*)

It is merely the stimulating effect of ether on the vasomotor centre that does it; but this lends to the operator a feeling of safety and confidence that he could never have with chloroform under the same conditions, and also secures best the safety of the patient who, until by operation the compressing cause can be removed, is really in a critical condition. But, in the ordinary case of cerebral tumor, the patient being in good condition for operation and his bulbar centres working well, one need not hesitate to use chloroform in the Vernon-Harcourt apparatus because of the numerous advantages which it possesses.

It seems proper to refer here to the few observations hitherto recorded upon cerebral operations under local anæsthesia. Heidenhain* seems to have been the first to use local anæsthesia in this way. He performed two operations with

* *Loc. cit.*

10 c.c. of one-half-per-cent cocaine with the addition of adrenalin. This was injected subcutaneously and also under the galea on the bone. After half an hour, anæsthesia was complete; and in the first case he was able to expose and extract a syphilitic sequestrum. Quite a long incision was made, the periosteum was pushed aside, a considerable amount of bone was removed with the chisel and Luer's forceps, and the dura was scraped—all without causing the patient pain. In the second case Heidenhain turned down an osteoplastic flap, removed the bone from it without pain, but did not touch the brain itself. He proposed that the skin-bone flap should be made under cocaine at the first operation, and a tumor removed at a second stage, all under local anæsthesia. Just lately Cushing* has published a report of the removal of a subcortical cyst at a second-stage operation, in which the incision of the dura mater and the incision of the cortex were equally painless. Mitchell † also has trephined the skull under local anæsthesia. The importance of this new departure for the avoidance of the stress and shock of narcosis is obvious. Cushing suggests the frequent discarding of anæsthesia, in all two-stage operations, for the second stage. I have tried to do this in one case after an interval of ten days, but the pain caused by reopening the skin incision forced a return to ether.

The Influencing of the Vital Centres.—Naturally, in spite of the best conditions obtainable in other respects, during the removal of a large growth, or during trephining in traumatic cases which are so often complicated by concussion, the bulbar centres become depressed; and it is important to adopt measures to maintain their functionating power. The signs of their failure are seen chiefly in the condition of the respiration and the circulation. As to respiration, all the variations which have been discussed in the chapter on Compression and Concussion as indicating threatening failure—in particular an increasing shallowness, a tendency to come in groups or to assume the Cheyne-Stokes type—all these have to be watched for with the greatest attention by the anæsthetist. The signs of circulatory failure are evidenced in the behavior of the vasomotor centre rather than in that of the heart itself; and to this our best guide is the peripheral arterial pressure. Upon this we have sufficiently insisted in other sections of this article. The heart-beat itself gives but little indication of danger; in fact, the heart is the last to die; it continues beating often five or ten minutes after respiration has entirely ceased. It is evident, therefore, that particular precautions and close observation are necessary during the conduct of cerebral operations. A special man should be detailed to keep a watch on the respiration, its rate and its character, and to take blood-pressure tests at short intervals. Where this extra assistance is not available, it would be valuable for the anæsthetist, as Cushing suggests, to auscultate the chest more or less continuously throughout the operation. This he can easily do with a phonendo-

* Thomas and Cushing, in Jour. of Amer. Med. Assoc., March 14th, 1908.
† *Loc. cit.*

scope provided with extra long rubber tubes; and in this way both respiration and cardiac action can be observed at the same time. The measures to be adopted in case of a threatened failure of these centres are not numerous. First, if severe compression is present, its cause must be removed, which means that operation must be hurried. For respiratory failure, one should give, according to Horsley, inhalations of oxygen, followed by strychnine; the latter, as he says, is our best stimulant of the bulbo-spinal centres. If respiration cease, artificial respiration must be made. Operations have been completed under artificial respiration, with the ultimate saving of the patient's life. With a blood pressure that falls much below 100 mm. Hg the operation had best be interrupted, and completed at a second stage. Horsley's proposal in 1893 to do the majority of cerebral operations, at least those for tumor, in two stages has doubtless saved many lives from death by operative shock. In the presence, however, of threatening vasomotor failure, the best immediate stimulant is an intravenous infusion of from one to two pints of salt solution in which is dissolved adrena-

FIG. 93.—Author's Modification of Frazier's Head-rest; Side View. Made of ordinary gas-piping. The head portion is made movable in two directions by inserting two elbows, the joints of which are made tight enough by screws to hold the head in any position. It can be moved up and down, or rotated round the vertical axis.

lin in the proportion of 1: 50,000. The latter may be given hypodermically also with good effect in the dose of 10 to 15 minims. Experimental work of Crile * and the clinical experience of many have shown that the effect of adrenalin is transitory. The observation of Butler † in this respect is encouraging, and indicates the value of an attempt to maintain the effect of the drug by giving it repeatedly. Butler appears to have saved his patient by giving hypodermics of adrenalin solution at two-hour intervals for two or three days. The ordinary cardiac stimulants are not of great use in this condition—they act chiefly on the cardiac muscle; whereas what is needed is an effect on the muscle walls of the vessels which carry on the peripheral circulation. Blood pressure must be raised, and at present adrenalin is the most efficient drug.

The shock that develops after operation and carries off the patient within the

* Crile: "Blood Pressure in Surgery." † Butler, in Lancet, March 3d, 1906.

first twelve or twenty-four hours is best combated, according to Horsley, by repeated enemata of beef-tea and pancreatized milk; but he advises also small doses of atropine and digitalis.

We now pass to the consideration of mechanical procedures, and shall take up in detail the various steps of the type operation of making an opening in the skull. While the operation of trephining has been practised from the very earliest days of medicine, it was Wagner who in 1887 first taught us the idea of making a temporary window in the skull by means of his osteoplastic-flap method; and at the present day the two methods—on the one hand, the permanent removal of the cranial bone, and, on the other hand, the temporary folding back of a por-

FIG. 94.—The Same, Front View.

tion of the bone—are in common use. They are not rival methods except in certain circumstances; each has its own indications. The English school as a whole, following Horsley, prefer to remove the bone permanently in most cases of tumor, while the German and American schools prefer to use the osteoplastic flap. The advantage of removing the bone permanently is that it gives the fullest amount of decompression. It allows also the soft parts to fall in and become adherent to the brain, thus often preventing cyst formation. Such a junction between the scalp and the brain, if healing has been aseptic, is most unlikely, according to Horsley, to be followed by epilepsy. The method is, moreover, elastic. One may remove as much or as little bone as is desired. The disadvantage is that the ultimate result, cosmetically, is poor.

The position of the patient on the table is important. Nearly all operators have the head of the patient somewhat raised in order to facilitate free return of the venous blood. Krause in cerebellar cases even has his patient sitting up. In conditions of severe compression, marked elevation of the head is to be deprecated because of the hydrostatic effect of gravity upon the exposed brain, which would place the compensating splanchnic vasomotor mechanism at a disadvantage and perhaps induce increased anæmia of the brain. If Crile's pneumatic suit be used as a substitute for the splanchnic vasomotor mechanism, the elevated position is quite justifiable.* Most surgeons use a particular

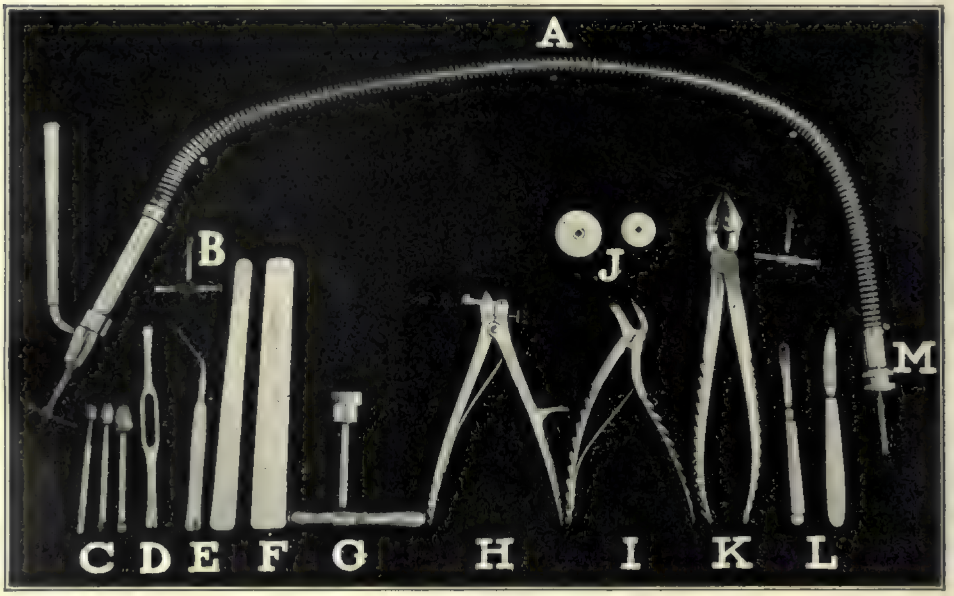

Fig. 95.—Instruments Commonly Employed in Brain Surgery. *A*, Flexible shaft, attachable by a chuck (*M*) at one end to an electric motor, and bearing at its free end a circular saw with guard and a convenient handle; *B*, Gigli saw with handles attached; *C*, three burrs of different sizes; *D*, sharp-edged periosteal elevator; *E*, Horsley's dural separator; *F*, Horsley's aluminum spatulæ; *G*, hand trephine; *H*, the de Vilbiss bone-cutting forceps; *I*, rongeur forceps; *J*, two circular saws fitted with circular rim guards to prevent cutting too deeply; *K*, Horsley's bone forceps; *L*, raspatories.

head-support which is either fitted on to the table or stands alone, thus affording an easy means of raising, lowering, or turning the head in any desired direction, of exposing better the suboccipital region in cerebellar operations, and of affording more room for the assistants. It also gives freer play to the thorax and prevents embarrassment of respiration. Horsley's head-support is the most elaborate and most expensive of these. Cushing uses a simple crutch separate from the table, the arms of which embrace the head and hold it firmly. Frazier attaches a simple support to the table. The writer's modification of Frazier's support is here illustrated. (Figs. 93 and 94.) It allows of movements of rotation as well as those of raising and lowering.

* Crile, in Jour. of Amer. Med. Assoc., Dec. 1st, 1906.

TREPHINING.—The present operation of trephining differs in no great degree from that practised by the Romans of the time of Celsus. The simplest and perhaps the safest of the various models is the Galt conical trephine with bevelled edge and loose central pin, as seen in Fig. 95, *G*. Apart from the muscular exertion required in its use, it is preferable to any electrically driven trephine. The older brace (Figs. 96 and 97) is convenient, and tires one less; but the manipulation of the centre-pin is sometimes bothersome, as it is apt to block. After exposure of the bone, the centre pin, advanced slightly beyond the saw edge, is sunk into the bone to give sufficient hold for the saw to make its furrow. This once made, the pin is removed, or (as in Fig. 97) pushed back within the plane of the saw edge; and the bone is then sawn through carefully. Bleeding from the diploë gives warning that the internal table is reached. A little more, and the trephine is to be removed, and an effort made to pry out the circle of bone. This is done with a narrow-bladed periosteal elevator. The writer has not found it necessary to use such devices as the old *tire-fond.* Several attempts, interrupted by a little further sawing, may have to be made before the bone can be lifted out; but it ultimately comes away without trouble or danger of wounding the dura. It may often be loosened by a rocking motion of the trephine.

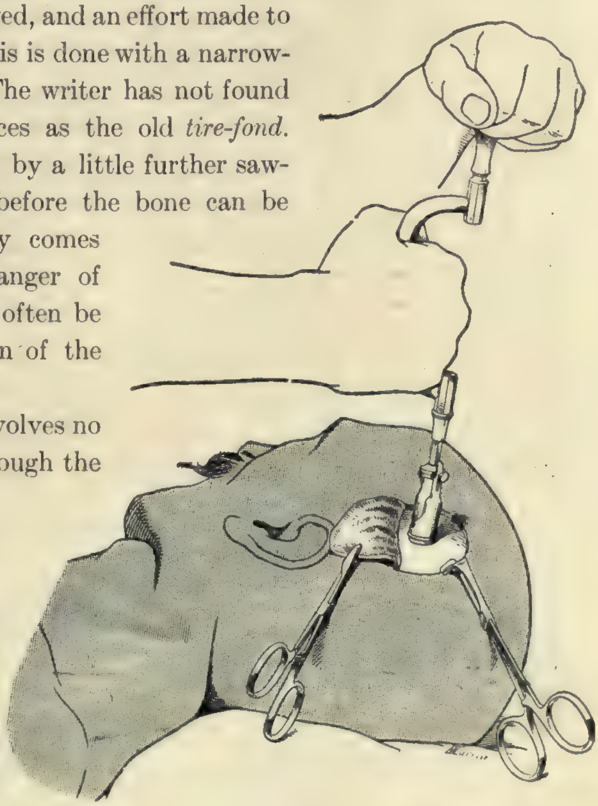

FIG. 96.—Manner of Using the Trephine. (Marion's "Chirurgie du Système Nerveux.")

In itself, the operation involves no danger save that of going through the dura and wounding the cortex. This should not happen with cautious sawing; although, where the dura is adherent to the bone at the site of an old injury, it may be difficult to remove the button of bone without slight tearing of that membrane. Rarely, an abnormal emissary vein may cause troublesome bleeding; Ransohoff even lost one patient from this cause. The measures to be adopted have been discussed above. The possible complication of bone infection at the site of trephining is guarded against by the especially careful technique which is so necessary in this work.

The trephine opening is nowadays rarely used, save in cases of depressed fracture, to give room for the raising of the fragments (see Fig. 98) or as the preliminary to a more extensive removal of bone; and for this purpose a somewhat smaller opening may suffice. Thus many prefer to use the Doyen perforator and burr, which are thought by some to be safer and speedier (see Fig. 95, *C*, and Figs. 99 and 100), though the writer has not found them so. These can be used either with an electric motor or with a hand-brace. Hartley has modified the cutting edge of the burr to advantage.

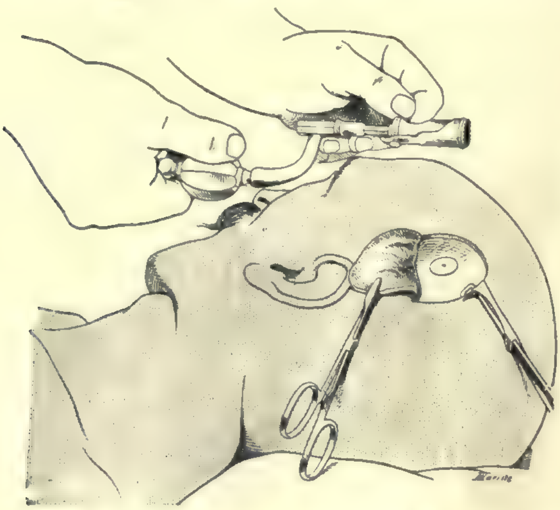

Fig. 97.—The Saw-cut has Penetrated the Bone Sufficiently to Render Unnecessary the Support of the Centre Pin. This, therefore, is now withdrawn; if left projecting, it would wound the dura mater before the saw had completely cut through the circle of bone. (Marion's "Chirurgie du Syst. Nerveux.")

The Making of a Permanent Window.—In operations for abscess, and for purposes of decompression, and in such small operations as ventricular puncture, the permanent opening is desirable; while in all cases in which the diagnosis is obscure and in which one may desire to close the wound without further effort, the osteoplastic flap is preferable. The primary opening is best made by means of a trephine, preferably of three-quarters or one inch in diameter, as described above. From the borders of this central opening the requisite bone is removed gradually by means of heavy biting forceps; of which Lane's model (see Fig. 101) is one of the best. If the bone is unusually thick, or if an especially large opening is to be made, the outline of the proposed window can be better made with a saw, either the circular saw run by an electric motor, or, as Horsley

Fig. 98.—Manner of Raising a Depressed Fracture. A trephine opening has been made, as will usually be necessary, at the edge of the depression, in order that an elevator may be inserted under the fragments. In the drawing, the trephine opening has been made somewhat too close to the area of the depression. (Marion's "Chirurgie du Syst. Nerveux.")

prefers, a simple hand-saw. This saw cuts to the inner table. A number of cross-cuts are then made from the central trephine opening outward, and the rough mosaic thus outlined is broken off in pieces with a heavy bone-cutting forceps. The forceps of Horsley is perhaps the best (Fig. 95, *K*); some operators prefer to use ordinary heavy rongeur forceps. In this way the bone is rather broken off in pieces than bitten off. It may be removed in large portions, and the exposure is thus made in less time than in the cutting of an osteoplastic flap. Care must be taken to separate the dura in advance from the bone with the dural separator (see Fig. 95, *E*), to avoid the danger of rupturing branches of the middle meningeal artery in breaking off the bone.

Fig. 99.—Doyen's Perforator.

The Osteoplastic Flap.—A great many methods and modifications have been proposed since Wagner first published this mode of opening the skull. Wagner himself and the earlier operators used the chisel and mallet altogether, a method which is now very generally abandoned. Apart from being slow, it is apt to produce concussion, for it resembles too much the "hammering" experiments of Koch and Filehne. Doyen devised a complete armamentarium especially for this purpose. It consisted chiefly of a perforator and burrs with which to make the necessary preliminary openings, and of a circular saw with which rapidly to join this row of openings. These instruments were operated either by electricity or by hand. The objection, that the saw might perforate the inner table and cut the dura, he obviated by attaching a dural guard, which slipped along underneath the bone, separating the dura as it advanced, and being separated from the cutting edge of the saw only by the thin inner table. The making of the preliminary openings is sufficiently obvious from the accompanying illustration. (See Fig.

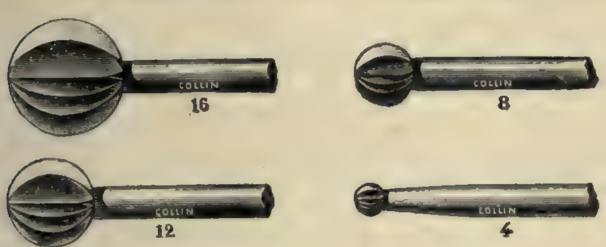

Fig. 100.—Doyen's Burrs, of Various Sizes.

Fig. 101.—Lane's Rongeur Forceps for Removing Bone in Craniotomy.

102.) The inner table was then broken by means of a chisel or by merely elevating the whole flap.

The general principle of sawing the bone from without by the use of instruments driven by electricity or compressed air has been variously modified since then. The chief modifications, however, consist in the dural guard and the use of the motor. The guard most frequently used at present consists of a metal rim screwed upon the circular saw so as to permit cutting only to a certain depth. By the use of different rims one may cut to any depth from 2 to 3 mm. up to 8 or 9 mm. Hartley's improved instruments are particularly good in this respect. Hartley also modified advantageously the scope of the motor. The ordinary steel flexible shaft, as indicated in Fig. 95, *A*, is very effective, but blocks easily whenever it is bent beyond a certain angle. The motor is carried on a table at the other end of the shaft. As one changes position in cutting the flap the table is moved about in order to preserve a fairly straight line for the shaft. This mechanism is cumbersome; so that Hartley's modification, consisting of a specially constructed motor enclosed in a sterilizable steel case light enough to be held by the operator, with also a flexible ordinary electric wire to communicate the current, constitutes a decided advance in this mode of operation. The reader is referred to Hartley's article.*

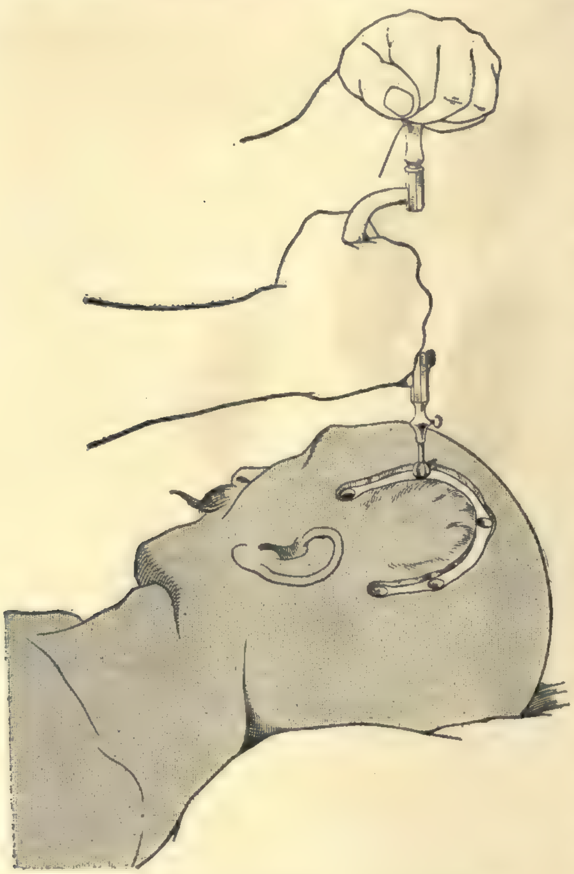

Fig. 102.—Technique of Raising an Osteoplastic Flap. An incision has been made down to the bone, and the flap with periosteum has been pushed slightly back with the raspatory; five trephine holes have been begun with the Doyen perforator, penetrating as far as the inner table; and the burr is being used to complete them. (Marion's "Chirurgie du Système Nerveux.")

A different principle of action was initiated by Cryer of Philadelphia in 1897, and an instrument based upon this principle was devised independently by

* *Loc. cit.*

Sudeck of Hamburg in 1900. The instrument consists in a fraise (illustrated in Figs. 103 to 105), which cuts on the side. The dura is guarded by a button on its end. A preliminary trephine opening is made. From this point a flap of any size may be cut. This apparatus is used almost exclusively by Frazier of Philadelphia, who claims that it works very effectively, safely, and quickly. I have tried it only on the cadaver. In infants and young children, and where the bone was very thin its action was good and rapid; in adults with thick skulls it worked very slowly, and broke on one occasion. I was assured in Philadelphia that such an accident had happened there but once and that it had done no harm. Cushing says that he knows of one instance in which the dura was perforated by the button at the end of the fraise.

Fig. 103.—Cryer's Spiral Osteotome. Compare with Sudeck's instrument.

The principle of action adopted by Cushing is that of cutting from within outward. Two openings are made at the upper corners of a rectangular flap, the first with the large trephine, the second with a Doyen burr; and the bone between them is then cut with a Gigli saw. The dura must be protected from the saw by some instrument, preferably Marion's. If the width of the flap is great, three openings are made. The sides of the flap are then cut with the Montenovesi and the Dahlgren forceps. The manœuvre of the Gigli saw is shown in Figs. 106 and 107; and the final reflection of the flap in Fig. 108. This method has the advantage of safety at some cost of speed. In the writer's experience, the Gigli saw is apt to break unless the holes are close together; and to make more openings and introduce the saw twice cause a loss of time.

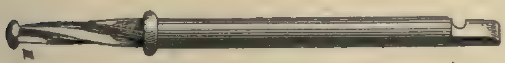

Fig. 104.—Sudeck's Fraise.

After all, each method has its own advantages and it is clearly a matter of individual preference or of individual habit. "Tools to the man who can use them." Cushing's method, as to the bone openings, is preferred by the writer, with the substitution of an electric circular saw for the Gigli saw. In cutting the bone flaps, it is of advantage to make a furrow down to the diploë with the circular saw, and complete the sec-

Fig. 105.—Sudeck's Fraise in Use. (Marion's "Chirurgie du Syst. Nerveux.")

tion either with a chisel such as Kuester's, with bayonet shape and dural guard (see Fig. 109), or with de Vilbiss or Dahlgren cutting forceps. The objection to the use of the chisel, because of concussion, is hardly valid when only

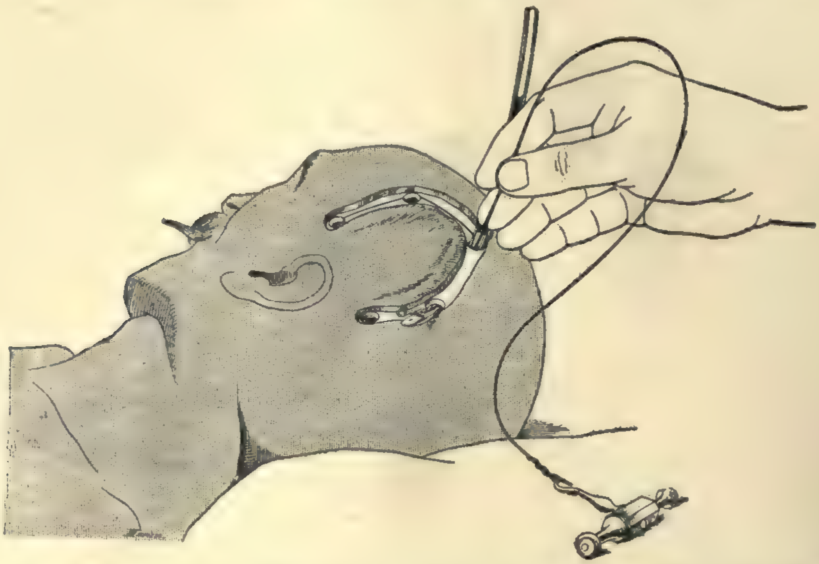

Fig. 106.—Marion's Guide and Dural Protector has been Passed between Two Neighboring Holes; and the Gigli saw is being run through along its gutter. (Marion's "Chirurgie du Syst. Nerveux.") Note that the number of trephine openings (five) here shown is entirely unnecessary with other methods, and so many are now rarely employed.

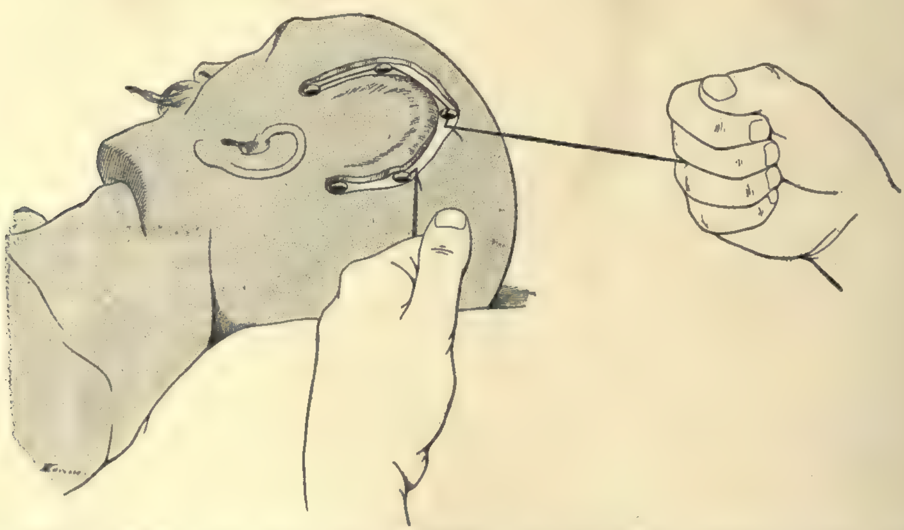

Fig. 107.—Section of the Bone with the Gigli Saw. Note that the bone is cut on a bevel. The angle at which the saw is held in the figure is much too acute; such a position infallibly breaks it. (Marion's "Chirurgie du Syst. Nerveux.")

the fragile inner table is cut; and it has the advantage of speed. It is hardly necessary even to cut entirely through the vitrea, as the leverage of a periosteal elevator inserted in each of the superior openings is sufficient to break the bone that is left uncut. The use of the circular saw at the top of the flap permits the making of the latter as wide as one likes without the necessity of more than one opening at each upper angle—that is, never more than two openings in all. It is the preliminary trephine openings that consume the largest amount of time.

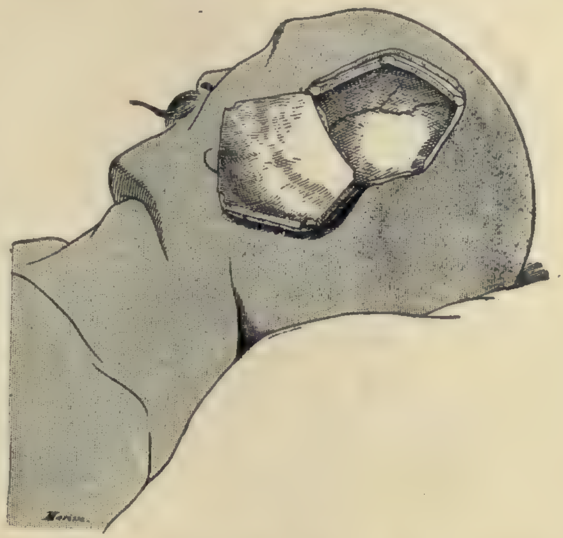

FIG. 108.—The Osteoplastic Flap has been Raised by Means of a Sharp-edged Elevator, the bone being fractured across the base of the flap; and the dura lies exposed. (Marion's "Chirurgie du Syst. Nerveux.")

Much emphasis has been laid by writers upon the necessity of bevelling the cut in the bone on at least one side in order that, when the button is replaced, it may not sink upon the dura mater. This is considered of importance because of the danger of the bony flap being forced in by pressure if the patient lies on that side; but it seems to the writer that this danger has been much exaggerated. The sutures passing through the whole thickness of the scalp support the bony flap very well, and except under unusual conditions there must be very little likelihood of the bone being forced inward. It is easy, however, with any of these instruments, except perhaps the Cryer fraise, to bevel the border.

FIG. 109.—Kuester's Craniotomy Chisel. (From photograph given to author prior to publication).

The shape of the osteoplastic flap will vary according to the degree of exposure desired. Yet, inasmuch as in all tumor cases the local diagnosis relates to a lobe, standard openings should be adopted for the exposure of the various regions. Frazier and Hartley * have described such standard openings. The principle emphasized by Hartley that the base of the flap should always lie as much as possible in the temporal region where the bone is thin, is valuable. The writer prefers irregular rectangular flaps with base narrower than top, to those of curved shape.

In making such flaps one should remember that there are several situations where hemorrhage may become profuse. Thus, when the base of the bone in

* *Loc. cit.*

the temporal fossa is broken, the middle meningeal artery may be torn across. This is easily caught. It should be ligated with catgut passed beneath the vessel on a needle. Toward the central line of the skull the presence of the lateral expansions of the longitudinal sinus, the "blood lakes," must be remembered. Bleeding from these may be very serious. It can often be arrested quickly by pressure with the finger on the sinus; and the application of a lateral suture is usually sufficient to stop it. Still I have on one occasion seen hemorrhage occur from these parasinoidal sinuses, wounded by the passing of a needle in the attempt to ligate the longitudinal sinus, so difficult to control as to require packing, and so profuse as to cause fatal shock. Under such circumstances the dura must be freely opened an inch or more outside the middle line on both sides, and a suture passed through the falx under the sinus, under guidance of the eye. Stratton * has called attention also to this danger.

The bone flap being reflected, further action depends upon the condition for which the operation has been undertaken. For tumor, the procedure of Horsley, who at this stage replaces the flap temporarily, and opens the dura only some days or a week later, is now rather widely adopted in a routine way. The only objection to it is a slightly greater liability to infection. I have found that if the stitches are left in over two or three days, this danger is very definitely increased. Under circumstances of urgency, or in traumatic cases generally, one will proceed without delay to turn back a dural flap. This may be done preferably by an oval or rectangular incision following the bone edge at a short distance from it so as to leave a convenient border for resuture. Under conditions of tension this is a delicate matter, for it is very important not to wound the pia-arachnoid. The latter membrane acts as a good envelope; but, if broken through, the cortical substance is apt to be herniated, with consequent bleeding. Therefore incise the dura cautiously, and, as soon as through at a small point, lift it up with forceps, and continue the incision with a pair of button-pointed scissors, at the same time introducing if possible a dural separator, and pressing the brain gently inward. If there is now disclosed no clear evidence of lesion, either on inspection or on palpation, it is justifiable to explore the brain in various directions. This should be done with a grooved director or a hollow needle if one suspect abscess or internal hydrocephalus, or with the scalpel if one suspect a subcortical tumor. In either case the centre of a convolution free of vessels should be chosen. If a tumor, cyst, or other lesion be found that demands excision, it is first necessary to ligate all the surface vessels in a circle surrounding the area to be attacked. This should not be done by artery forceps and ligature, for the vessels are delicate and so little supported that it is almost impossible to avoid tearing them; the ligature should rather be passed by means of a small round needle. (See Fig. 110.) A very fine non-absorb-

* Stratton, in Annals of Surgery, Aug., 1898.

able material is used for ligature, as catgut cannot be obtained fine enough and strong enough for the purpose. Horsley uses the finest silkworm gut, such as is employed by the ophthalmologist. Cushing uses split black silk. Horsehair is also effective. The incision is then made with a knife down to the tumor, if subcortical; and the tumor is dissected out bluntly, following its outline. The practice of shelling out the growth with the finger is to be condemned, because such manipulations cause pressure toward the interior; and, according to Horsley, all application of force should be toward the exterior. Besides, the finger is a coarse and correspondingly destructive agent by reason of its very size. Gliomata must be excised cleanly and widely, where their limits can be determined, as with any other malignant growth. The oozing from the cerebral substance is stopped by very cautious irrigation or light sopping with saline solution at 115° F., or, if this fail, by the insertion of pledgets of dry absorbent cotton, a material which I have found to be one of the best hæmostatics for all oozing surfaces. The use of oxygen is advised by Horsley where oozing is chiefly venous and due to the rise in venous pressure from chloroform asphyxia. It is applied through the Vernon-Harcourt inhaler as shown in Fig. 91. In any case all actual sponging of the exposed brain, as is usual in operations elsewhere, must be rigorously avoided. If bleeding does not cease with these measures, it may be assumed that a somewhat larger vessel has been wounded. It may be tied by passing a ligature through the cerebral substance adjacent to the vessel by means of a curved round needle. Such vessels, fortunately, are infrequent in the cerebral white substance, at least in regions upon which one ordinarily op-

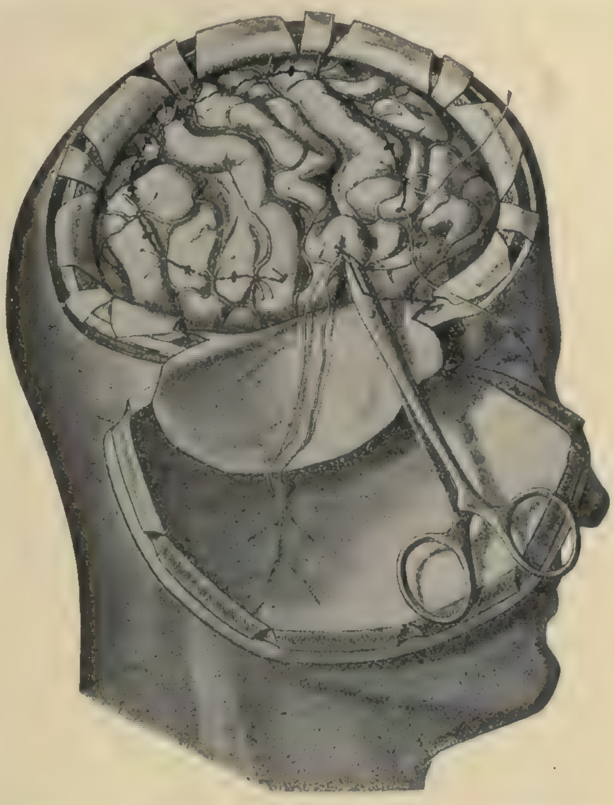

FIG. 110.—Jonnesco's Hemicraniotomy, with Resection of the Cortex in Cases of Genuine Epilepsy. The figure is reproduced only in order to illustrate the method of ligating the cortical vessels in a circle, which is a necessary preliminary to resections of brain tissue. Exposures as large as here indicated, or such a wide ligation of vessels, are to be condemned. The ligature material as shown is also much too coarse. (Chipault, "État Actuel," etc., vol. iii., p. 541.)

erates. The leaving of a gauze tampon in such a cavity can be justified only by the persistence of hemorrhage, impossible to control otherwise. Ordinarily, the cavity thus left will close spontaneously by collapse of the walls.

The manner of closing the operation wound will differ according as the bone flap is removed or not. In the former plan the dura is laid loosely on the cortical surface, without stitching, and the soft parts of the scalp are accurately sutured together, usually without draining. In the latter the dura is carefully resutured. Any space left by the removal of a large growth is immediately filled by collapse of the walls, and by the exudation of serum and cerebro-spinal fluid. Cushing has found that adhesions of the dura to the brain are prevented by accurate suturing. The flap of bone and scalp is then replaced.

The chief bleeding vessels of the incision are ligated; or one may perhaps trust to a close-set continuous suture to control all hemorrhage. It is a rapid and efficient method, but not neat, nor always reliable. Cushing, indeed, places and ties all scalp sutures before removing the tourniquet, which seems to be sufficient without individual ligatures. Exact approximation of the edges and fairly close-set stitches are, however, necessary. The sutures may be removed within three or four days where there is no fear of material tension on the part of the brain, and it is well to remove them early in order to avoid stitch infections. The line of incision may be reinforced with strips of adhesive plaster rendered aseptic. Drainage is to be avoided wherever possible.

Faradization of the Cortex During Operation.—Under certain circumstances, particularly in cortical excisions for Jacksonian epilepsy, it will be necessary to localize accurately by means of faradism the function of the exposed convolutions. Since Sherrington's work in 1901 it is customary to use a unipolar platinum electrode for cerebral excitation, with a very large flat electrode which is placed on another part of the body, usually the arm or leg of the same side. Cushing seems to have done most of the work in this line upon the human cortex, and he has devised a glass carrier for the electrode. The current should be just strong enough to contract exposed muscle; the occipito-frontal or temporal fibres are usually close by. The cerebro-spinal fluid must first be evacuated from the subarachnoid space by pricking the membrane. The anæsthesia should be light. Under these circumstances, he says, no normal motor cortex fails to give a response; and the nature of the response gives the localization.

XXIII. CRANIO-CEREBRAL TOPOGRAPHY.

There is a well-marked tendency of late, in contrast with the extremely exact and painstaking work of various former anatomists, to lay less stress upon the exact outlining on the scalp of the underlying fissures and convolutions. This is clearly the result of certain factors: in the first place, and chiefly, the coming up of a school of neurological surgeons who are able with great certainty to "visualize" the cerebral geography through the intact skull without the necessity of making accurate measurements; in the next place, the general adoption of a large osteoplastic flap or permanent opening, which renders unnecessary the attempts at absolutely exact extracranial localization; and, finally, the recognition of the fact that, because of individual variations in the disposition of the various gyri, it is almost impossible to expect mathematical accuracy in any method. So that we find that those surgeons who do most in this field dispense almost entirely with pre-operative skull markings. This is the natural

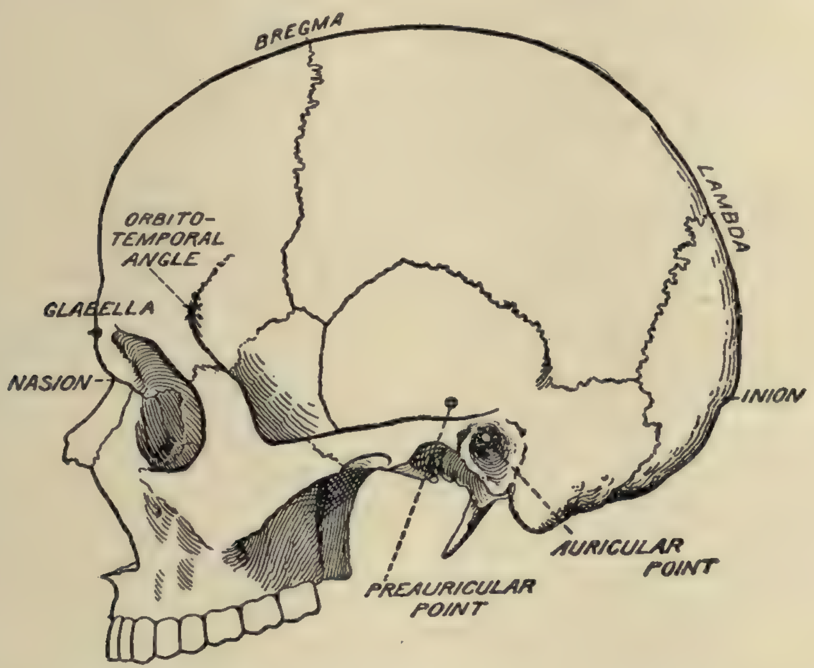

FIG. 111.—To Illustrate the Position of the Chief Points Concerned in Cranio-cerebral Topography. (For description, see text.)

result of specialization. But, inasmuch as many cerebral operations must still remain in the hands of men who are less familiar with the anatomy of this region, the necessity for consideration of these cranial measurements in text-books is still present. If one, however, reviews the large number of different methods which have been worked out by surgeon-anatomists, it becomes evident that all are more or less accurate, varying from each other very slightly. There is, therefore, hardly any necessity of giving details concerning many of them. If the operator will choose a reliable one, it will be found sufficient in all cases. Frazier uses the Anderson-Makins method; Hartley the Chipault lines; the Germans use largely either Kocher's or Kroenlein's; the French, Broca's, Chipault's, or Poirier's. The writer finds Kroenlein's method very satisfactory. Taylor and Haughton's is also very efficient; and these two will here be described.

First, however, the more important of the bony landmarks commonly referred to in the literature of cranial topography may be briefly enumerated. (See Fig. 111.)

The nasion represents the depression at the junction of the frontal with the nasal bones; the glabella is a transverse ridge joining the prominences of the eyebrows; the inion is the external occipital protuberance; the junction of the coronal and the sagittal sutures in the mid-line is called the bregma; the mid-sagittal point is half the distance between nasion and inion. The lambda lies at the junction of the occipital and parietal bones in the middle line and is easily recognizable as a distinct depression. The arterion marks the postero-inferior angle of the parietal bone, at its junction with the occipital and temporal bones. Other landmarks are: the external angular process of the orbit, the middle of the zygomatic arch, the external auditory meatus, and the tip of the mastoid process. The chief lines of orientation are: the sagittal, the Rolandic, and the Sylvian fissures.

In order to mark out the line of the Rolandic fissure on the skull it is necessary to determine the situation of its superior and inferior points; the line joining these two points represents the general course of the fissure, although it is understood that the fissure itself is sinuous, and that the straight line of the cranial surface may overlie at any given point, not the fissure itself, but the anterior or posterior convolution. The Sylvian point represents the bifurcation of the Sylvian fissure; the course of the fissure corresponds roughly with a line joining the nasion with the lambda.

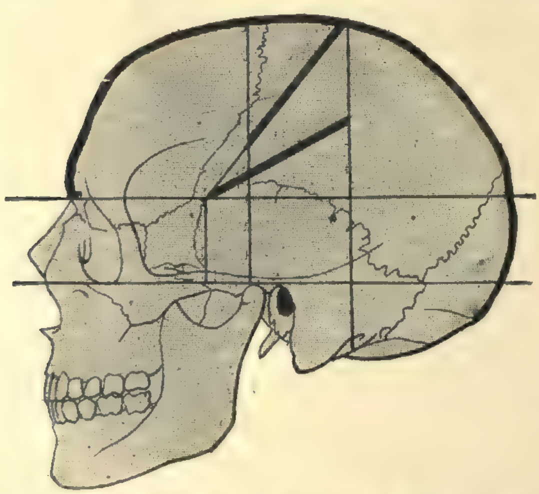

Fig. 112.— Kroenlein's Craniometric Method. The heavy black lines indicate the fissures of Rolando and Sylvius. (For description see text.)

The parieto-occipital fissure, which is of decidedly less importance, lies opposite to or a little above the lambda; that is, according to Thane, 6.5 cm. above the inion; or, according to Anderson and Makins, seven-eighths of the distance from the mid-sagittal point to the inion.

For Kroenlein's method (Fig. 112) there are drawn two horizontals. The lower one is the German "base line," which runs through the inferior edge of the orbit and the upper edge of the auditory meatus; the other is called the upper horizontal, and runs parallel to the first on a level with the upper border of the orbit.

Upon these two horizontals are erected three perpendiculars: one from the posterior border of the mastoid process; one just in front of the external auditory meatus, rising from the condyle of the lower jaw; and one from the middle of the zygoma. The superior Rolandic point is found at the spot at which the posterior perpendicular strikes the mid-line. To mark the Rolandic line it is first necessary to establish the Sylvian point. This is found at the intersection of the upper horizontal with the perpendicular rising from the middle of the zygoma. The inferior Rolandic point lies at the intersection of the perpendicular from the

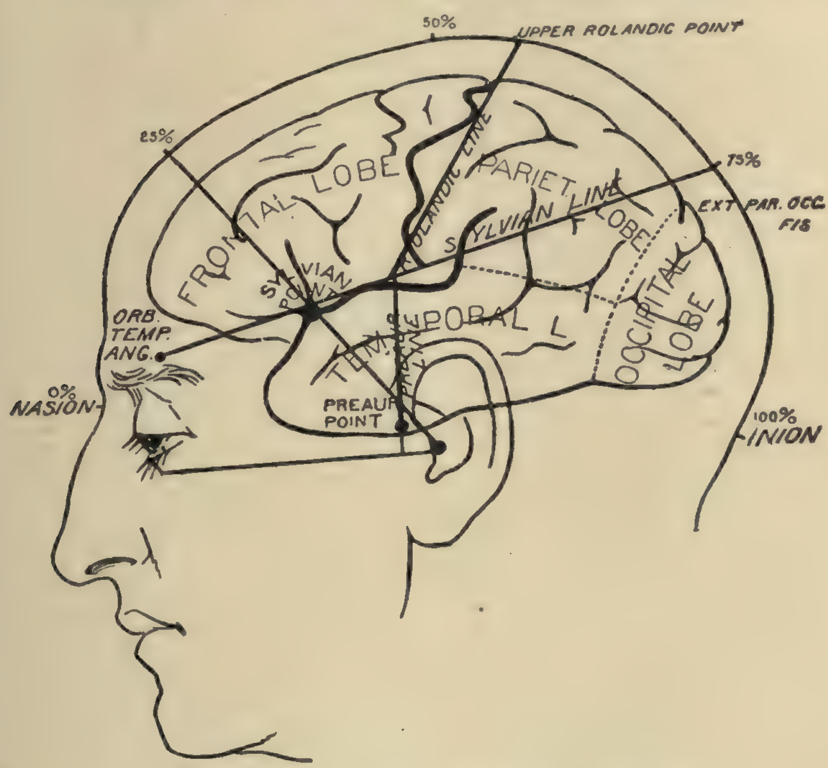

FIG. 113.—Taylor and Haughton's Method. (See text.)

condyle with an oblique line drawn from the superior Rolandic point to the Sylvian point; and the line between the superior and inferior Rolandic points indicates the course of the Rolandic fissure. A line bisecting the angle which the Rolandic line makes with the upper horizontal, and running from the Sylvian point to the retromastoid perpendicular, indicates the course of the Sylvian fissure. Kroenlein has devised a simple apparatus consisting of a framework of pliable metallic bands which can be fitted to the side of any skull. The bands are movable so that they may be placed along the lines indicated in his method. I have not found such an apparatus necessary.

In Taylor and Haughton's method * (Fig. 113) the Sylvian line runs from

* Taylor and Haughton, in Trans. Royal Acad. of Ireland, 1900, vol. xviii.

the external angular process to a point on the mid-sagittal line which is seventy-five per cent of the distance from the nasion to the inion. The superior Rolandic point lies three-quarters of an inch behind the mid-point on the naso-inionic line. The inferior Rolandic point lies at the junction of the Sylvian line with a perpendicular drawn through the pre-auricular point from Reid's base line (horizontal through lower edge of orbit and external auditory meatus). To find the Sylvian point a line is drawn from the external auditory meatus to a point marking one-quarter of the sagittal line from nasion to inion. The Sylvian point lies at the intersection of this line with the Sylvian line.

Where one wishes to determine only roughly the general direction of the Rolandic fissure, the old method of Chiene is quite sufficient. It consists in drawing a line from the superior Rolandic point forward and downward at an angle of 67° with the mid-sagittal line. The angle is easily calculated by taking three-quarters of a right angle; and this is easily got by folding a rectangular piece of paper at one of its angles one and a half times, then unfolding one-quarter of the way so as to leave an angle which represents three-quarters of a right angle, in other words 67°.

The writer has found it convenient, in using Kroenlein's method, to have sterilized tapes in readiness, which after the cleansing of the scalp can be quickly laid on the skull according to the lines indicated. The necessary points of intersection for the Rolandic line are then marked by a scalpel and the course of the fissure mapped out with a thin swab dipped in tincture of iodine. If necessary the fissure of Sylvius is also marked, and at the same time the outline of the proposed flap or point of application of the trephine. The gauze cap and tourniquet are then applied. Upon baring the field of operation one has only to cut in the course of the iodine lines. The whole matter takes no more than a minute or two.

Aside from these topographical lines there are certain general landmarks of importance. The upper border of the zygoma lies opposite the floor of the middle fossa and represents the lower surface of the temporal lobe. The occipital lobe rests upon the tentorium which is attached along the superior curved line; this represents, also, the course of the lateral sinus. The Sylvian fissure runs from a point underneath the anterior angle of the parieto-squamosal suture upward to a point just below the parietal eminence; and the centre of the fissure is found at least two inches above the zygoma. One is apt to have an erroneous idea that the Sylvian fissure lies much lower than this, and that the Rolandic fissure comes well down on the side of the vault. It must be remembered that the latter is really more on the upper surface of the hemisphere than on its side; its course lies entirely under the parietal bone. The mid-sagittal point lies approximately in the line of the perpendicular drawn from the external auditory meatus; and the superior Rolandic point three-quarters of an inch behind this.

The parietal eminence overlies approximately the supramarginal gyrus; the frontal eminence corresponds to the second frontal convolution. Broca's convolution lies at the anterior inferior angle of the parietal bone.

With the cortex widely exposed it is necessary to be more or less familiar with the position of the more central parts of the brain. In tapping the lateral ventricles, one must avoid the Island of Reil for fear of hemorrhage, and the Sylvian point is the best guide to this. The insula in its turn is a guide to the position of the basal ganglia which it covers.

Ventricular Puncture.—The outline of the lateral ventricle, referable to the cerebral cortex, should be known; its roof lies about two inches from the upper surface of the brain (Fig. 114). The operation of tapping the ventricles

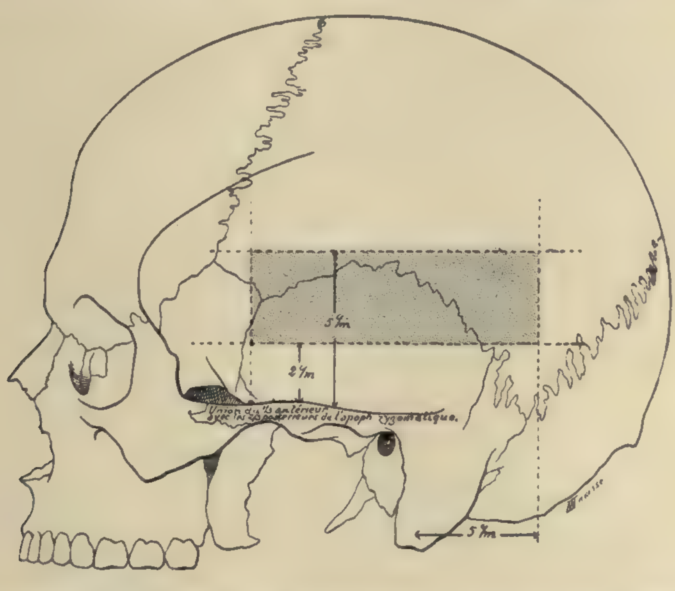

Fig. 114.—Relation of the Lateral Ventricles to the Exterior of the Cranium. (Marion's "Chirurgie du Syst. Nerveux.") Note: The upper level lies 5 cm. above the zygomatic arch; the lower 2 cm. above it. The anterior limit is indicated by a vertical running through the junction of the anterior third with the posterior two-thirds of the zygoma; the posterior limit, by a vertical situated 5 cm. behind the tip of the mastoid process.

is usually carried out either from the frontal or from the lateral aspect. In 1888 Keen laid down the rules to follow for penetrating from the side. The needle should be inserted at the posterior end of the second temporal convolution, at a point one inch and one-quarter behind the external auditory meatus and the same distance above Reid's base line running across the auditory meatus. The needle should be thrust in the direction of a point vertically over the opposite meatus and two and one-half or three inches above it. At a depth of two or two and one-quarter inches the normal lateral ventricle is reached either at the beginning or in the course of the descending cornu.

Keen also pointed out the possibility of doing the operation from the front, by taking a point from one-half to three-quarters of an inch at either side of the median line and one-third of the distance from the glabella to the upper end of the Rolandic fissure. Here the bone is trephined, the dura incised, and the needle or director pushed forward in the direction of the external occipital protuberance, traversing the first frontal convolution. The normal ventricle is found at the same depth of two to two and one-quarter inches. A. Kocher has demonstrated that the whole procedure may be done easily under local anæsthesia, a burr being used instead of a trephine for making the small opening.

XXIV. SPECIAL PROCEDURES.

(1) **Closure of Cranial Defects.**—It is unnecessary to recount the long discussions for and against the closure of cranial defects.* The practice of Horsley is to leave bone out in most tumor operations, and no ill effects follow. The size of the gap is probably immaterial in most cases, and symptoms are not due to any aseptic union of cortex with scalp. In old traumatic cases,

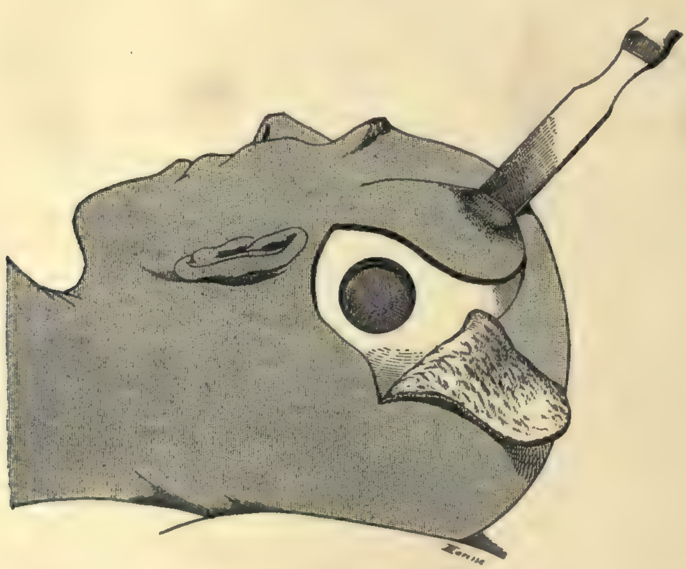

FIG. 115.—The Wolff-Koenig Method of Closing a Cranial Defect (here an old trephine opening). The defect being exposed, a flap has been cut which is to include soft parts, periosteum, and external table, the latter being raised by the chisel. (Marion's "Chirurgie du Syst. Nerveux.")

especially those that have healed with suppuration, symptoms may be due to the manner of union. Horsley rebuts the argument that it is useless to excise cortico-dural scars for the relief of epilepsy because the old is merely replaced

* Stieda, in Arch. f. klin. Chir., Bd. lxxvii., Heft 2.

by a new scar, by saying that the difference between aseptic primary healing and that by secondary intention is of paramount importance, and that his experience does not show that epilepsy develops after the former.

If for cosmetic or other reasons it be advisable to close a cranial defect, it may be done in several ways. The ordinary procedure is that devised by Koenig and by Wolff independently, based upon the old principle of Ollier—that of autoplasty by sliding. A flap of skin, soft parts, periosteum, and the external table of the bone (the latter being chiselled off on the flat as illustrated in Fig. 115) is slid so as to cover the defect, which latter has previously been bared by the cutting of a similarly shaped flap involving only the soft parts. The two are then made to exchange places. (Fig. 116.) Accurate fitting of the respective borders is impossible because of the pedicles, but the gaps left are partly closed by undermining of the edges and proper suturing, the rest being left to granulate; or a Thiersch's graft may be employed. The details of the procedure are sufficiently illustrated by the figures.

Fig. 116.—The Flap, Constituted as Indicated in Fig. 115, has been Brought over to Cover in the Defect. The original flap, that which was reflected from the defect, is now to be brought across to cover the area denuded of the external table. (Marion's "Chirurgie du Syst. Nerveux.")

The method of closing such defects by means of celluloid or metal plates has won a place for itself, by its success in the hands of some surgeons. Celluloid seems to be on the whole the most convenient and effective material, and is remarkably well tolerated by the tissues. Its smoothness prevents adhesion of the meninges. It should, at least, be reserved for large defects which are not easily closed by autoplastic methods.*

(2) **The Question of the Two-Stage Operation.**—That Victor Horsley's practice of doing operations for cerebral tumor in two stages has not been uniformly adopted is due probably to one reason only—to the fear that infection will creep in as the result of the reopening of a partly healed incision. The breaking of granulation tissue, the less easy and less thorough disinfection of the scalp at the second operation, and the frequent development of minute granulating patches at the corners of the resutured scalp wound, each of which is apt to har-

* Fedoroff, in Arch. f. klin. Chir., Bd. lvii., p. 728.—Borchhardt, *ibidem*, Bd. lxxx., Heft 2. —Beck, in Annals of Surgery, Aug., 1906.—Blecher, in Deut. Z. f. Chir., 1906, Bd. lxxxii., p. 134.—Wyeth, in N. Y. Med. Rec., March 3d, 1906, p. 356.

bor bacteria from the open skin, are objections of which, despite the authority of Horsley, it is difficult to divest one's self, especially as occasionally fear turns to fact. It is, therefore, as to the two-stage operation in any given case, a matter of the surgeon's judgment. Is there more danger to the life of this patient from shock if one completes the operation at once than from infection if it be postponed for a second stage? For this judgment an accurate knowledge of the condition of the patient's vital centres is necessary; and this can be best obtained by a graphic record of the respiration, its rate and character, the rate of the pulse, and the blood pressure. The making of such charts is now a more or less routine accompaniment of cerebral operations, especially in the services of those who do most in this line of work; and it is proper, when one possesses such accurate means of estimating the degree of shock at a given moment, to deter-

Fig. 117.—From Fraser's "Guide to Operations on the Brain."

mine the question of operative action upon this basis, rather than to adopt the two-stage plan as a routine measure. This is the point of view at present most widely held, I believe, on this side of the Atlantic. As a matter of fact, the condition of the patient after the bone flap is turned down is frequently such as to make it wise to defer further procedure for a time; and this is particularly true in the case of those in whom the signs of moderate or severe general compression are present. These patients stand interference, especially with loss of blood, very poorly; and if the indication for the relief of pressure is not immediate, one will usually do well to wait. However, the second part of the operation may be proceeded with in patients in whom, before the operation, the bulbar centres are not materially affected, intracranial tension is not great, and blood pressure has not fallen to any serious extent. Experience reveals the fact that the cerebral part of the operation is less shock-producing than the laying back of the bone flap.

(3) **Displacement of the Brain.**—It is Sir Victor Horsley who, more than any other, has demonstrated the feasibility of removing tumors from the basal region of the brain and skull, till very lately considered inaccessible, by virtue of the principle that the brain may be considerably displaced without causing serious symptoms of compression. The establishment of this fact was one of the results of his earlier experimental work upon local compression. But Horsley's remarkable series of eleven pituitary tumors surgically removed (unfortunately as yet a mere reference during the course of his remarks on technique at the Toronto meeting [1906] of the British Medical Association) prove it feasible in the human being; and they also seem to show that it is possible to lift the

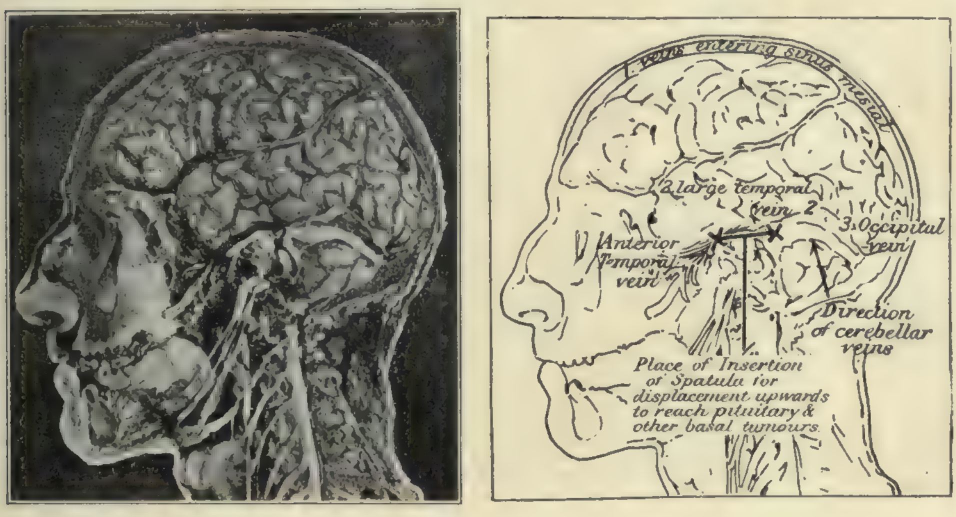

Fig. 118.—From Fraser's "Guide to Operations on the Brain." (See text for explanation.)

temporal lobe sufficiently to allow good access to, and in particular good oversight of, the middle line of the base.

The procedure is allowable upon two conditions: first, that the chief emissary veins which anchor the cerebral hemisphere to the dura mater shall be spared; second, that the displacement shall be effected by very slow and gradual compression.

The first is necessary because of the risk of softening if these nearly terminal vessels be ligated. Those concerned are (i) the cortical veins running into the longitudinal sinus; (ii) the temporo-sphenoidal vein to the lateral sinus opposite the asterion; (iii) the external occipital vein; (iv) the anterior temporo-sphenoidal vein. (See Figs. 117 and 118.) The spatula is inserted between the two temporo-sphenoidal veins at the point indicated in Fig. 117, when the temporal lobe has to be lifted in operations in the middle fossa. The elevation of the brain must be very gradual, and, when complete, the spatula must be held with the greatest steadiness by the assistant who should have some firm support for his elbow.

With this procedure and with a good light at his command Horsley is able to examine properly "the crura cerebri, the circle of Willis, the pituitary body and internal carotid, and the second and third nerves." In the posterior fossa, by slow continuous pressure from the lateral surface, as indicated in Fig. 117, he can "inspect the lateral region of the cerebellum and medulla oblongata with the issuing nerves." Horsley therefore considers unnecessary the proposal of Frazier to excise part of one hemisphere of the cerebellum in order to gain access to tumors at the cerebello-pontine angle. If, however, there is present severe subtentorial pressure, such as may be expected when the tumor is large or when complicated by a hydrocephalus, any one but Horsley will sometimes find it necessary to resort to Frazier's plan, or else to adopt that of Cushing, who proposes a second opening in the other half of the occipital bone to allow the lateral displacement of the opposite cerebellar hemisphere. Otherwise the crowding back of the cerebellum into the bone opening is so great as to render it almost impossible to get near the anterior pole of the hemisphere. Such, however, are not the more frequent cases.

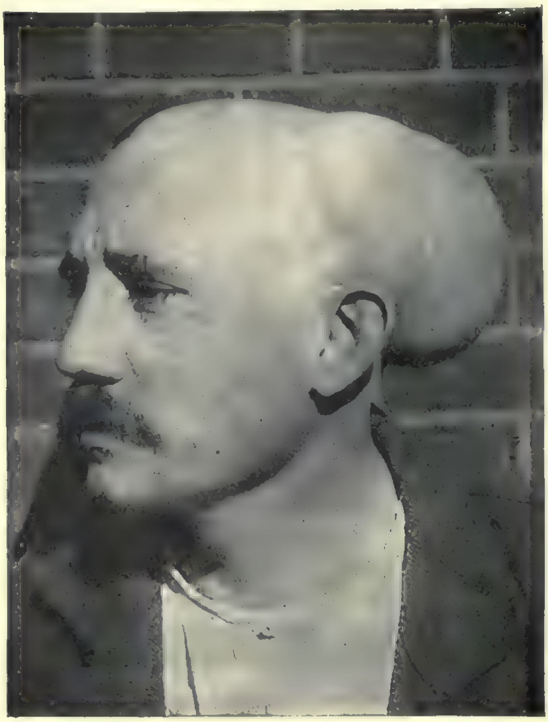

FIG. 119.—Enormous Left Parietal Hernia, one Year after Removal of Bone for Decompression. (Cushing: "Establishment of Cerebral Hernia," etc. *Surgery, Gynæcology, and Obstetrics*, Oct., 1905.)

(4) **Temporal and Occipital Operations for Decompression.**—*a.* THE TEMPORAL OPERATION.—The accompanying figures from Cushing's article illustrate the general principles and the value of the temporal muscle as a covering in cases in which one seeks to establish a cerebral hernia for the relief of compression. The principle is that such a hernia should be controlled, and should also cause as little deformity as possible. Figs. 119 and 120 show the appearance during life of an uncontrolled parietal hernia, and the anatomy of tumor and hernia as found at post-mortem examination. Doubtless even a subtemporal operation would not suffice to control such a massive hernia as this; nor might it

be well if it did. Nevertheless, the depth of the temporal fossa serves to disguise a protrusion which would be unsightly over the convexity (compare Fig. 121), and the control on the part of the muscle may be expected to prevent the exuberant, partly unnecessary extrusion of cerebral tissue, as a result of which function is apt to be widely abolished.

The steps of the operation are briefly as follows: A curved incision, following the temporal ridge and just within it, is made through scalp and aponeurotic membrane, which are then dissected off the temporal fascia and turned downward. An incision is now made through this fascia parallel to the muscle fibres,

Fig. 120.—Drawing of a Section of the Brain, which Passed Nearly through the Centre of the Tumor Mass. Note the deflection of the anatomical structures toward the hernia: the ventricle, for example. (Compare Fig. 119.) (Cushing, in *Surgery, Gynæcology, and Obstetrics*, Oct., 1905.)

and the muscle is separated down to the bone. Retractors draw the two halves of the muscle as widely apart as possible. The bone is then trephined, and further removal accomplished by rongeur forceps. (Fig. 122.) An opening of 6 cm. vertically by 8 cm. antero-posteriorly is obtained without difficulty. The dura is then removed close to the bone edge, exposing the temporal lobe in large part. Finally the split muscle is simply sutured over the bare cortex, preferably with fine silk, the fascia is likewise closed, and the scalp is sutured without drainage.

b. The Occipital Operation.—This operation, in the writer's experience, is a less satisfactory, more formidable, and more dangerous procedure than the temporal one. Bleeding may be considerable, and the access, though not really difficult, is not nearly so easy as in the temporal region. The chief reason, doubtless, is that many of the subtentorial lesions (for which alone this approach is justifiable), if irremovable, are apt to cause an obstructive hydrocephalus; and, if this be acute, it becomes almost impossible to control the hernia. Figs. 69 and 123 illustrate the destruction of the two cerebellar hemispheres consequent upon such an exploratory and decompressive operation for supposed cerebellar tumor, in reality a medullary glioma with hydrocephalus. If the patient live, the cerebellar signs previously present are apt to be increased. Nevertheless, inasmuch as the original cause forces one always to direct exploration, it will probably be frequently necessary, the tumor not being discovered, to accept this mode of decompression. It has also the advantage over the temporal or parietal regions that, if hydrocephalus be present, the dislocation backward of the whole region gives the best chance for the relief of obstruction and the re-establishment of the ventricular exits. For this purpose the bilateral operation with cross-bow incision, as recommended by Cushing, is theoretically the preferable mode. The objection to it is its extensive character, particularly as many of the patients are children. Frazier recommends a less formidable procedure, consisting in a simple split-muscle operation through a four-inch vertical incision, on one or, if necessary, on both sides of the middle line.

Fig. 121.—Patient Two Years after an Intermusculo-temporal Operation, with Complete Alleviation of Symptoms during this Interval. To show the comparatively slight and unobtrusive extent of the hernia. (Cushing, in *Surgery, Gynæcology, and Obstetrics*, Oct., 1905.)

The objection, again, to this is that decompression in the suboccipital region is practically never undertaken for that purpose alone. The operation is always begun in the idea of radical removal; and for such the split-muscle access is likely insufficient. The same reason may be urged against the primary bilateral exposure; for the radical removal of a unilateral lesion it is unnecessarily wide and shock-producing. And the argument that the side of the lesion cannot often be diagnosed falls to the ground since the paper of Stewart and Holmes. The Queen's Square men seem to have long been able to determine, with reasonable accuracy, the side of the cerebellum affected.

Thus it is probably best to expose first the cerebellar hemisphere to which the diagnosis points, and preferably by a superior curved and median vertical incision. Through a wide unilateral opening, the ordinary hemispheral growth can be removed. If no growth be found, the other side can be exposed (usually a second stage will be necessary). This will amount to Cushing's cross-bow incision, as described below. With a negative result here also, the operation becomes a decompressive one, and, if thought necessary, the intervening occip-

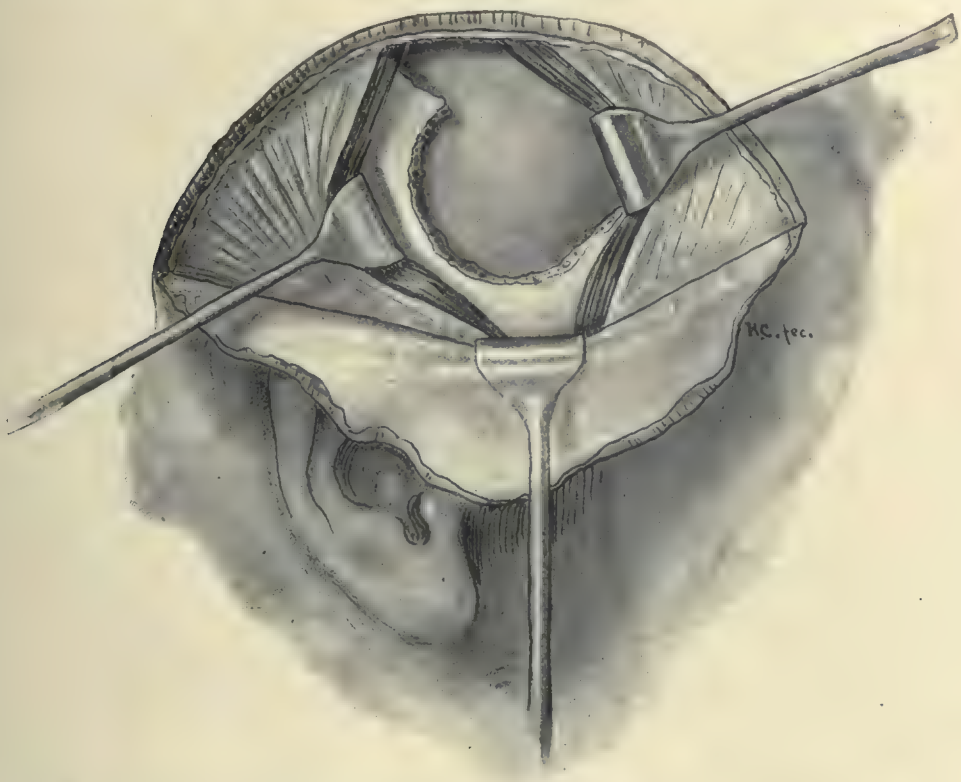

FIG. 122.—Sketch of the Intermusculo-temporal Field of Operation, Showing Exposure with Bone Defect Partially made. (Cushing, *loc. cit.*)

ital bridge may be removed. As Horsley has long been accustomed to do, the bone may be removed by the rongeur as far as the foramen magnum, for the purpose of giving greater space to the cerebellar tonsils and medulla which are depressed into that opening. The writer followed this procedure three years ago in the case shown in Fig. 123, with relief which lasted only an hour or so, as seen in the regularization of a very slow Cheyne-Stokes respiration. In another cerebellar case (Fig. 124) the evacuation of an extra-cerebellar sub-arachnoid cyst became practically no more than a decompressive operation because of the later refilling of the space from an unsuspected portion of the cyst, extending through the middle and anterior fossæ. The amount of decompression afforded is seen in Fig. 124, and the relief of symptoms was for some time most marked.

The steps of the suboccipital operation, radical or palliative, are as follows: The incision is best made, as Cushing advises, rather high (Fig. 125), for the reason that, after operation, the weight of the head on a low incision may induce decubitus, as happened, indeed, to one of the writer's patients. The incision should extend, therefore, from the posterior edge of the mastoid a little above the superior curved line to the middle line, and here be joined by a vertical

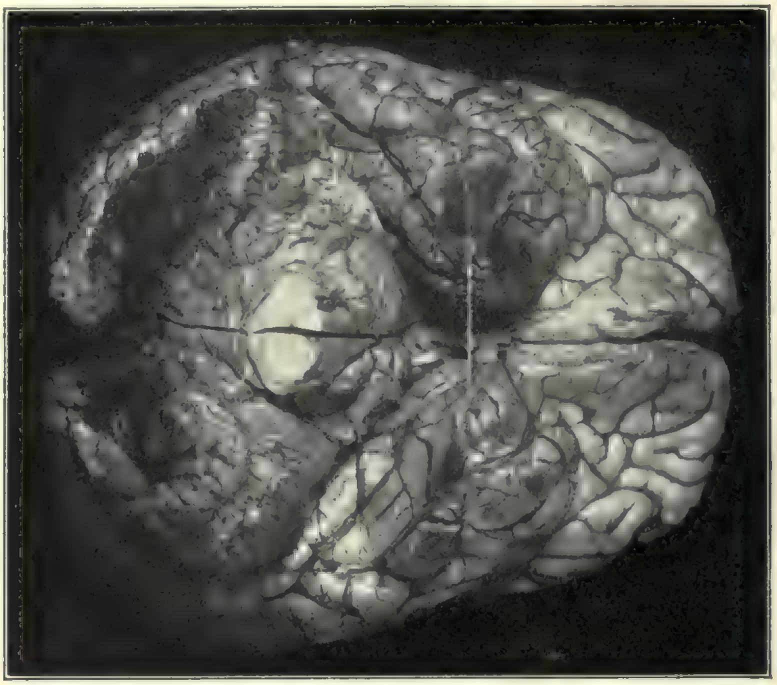

Fig. 123.—Brain of Case in which the Major Part of the Occipital Bone was Removed for the Relief of Pressure. An inoperable tumor of the medulla giving cerebellar signs, and complicated by acute hydrocephalus, was present. Note the large destruction of both cerebellar hemispheres posteriorly (dark area) as result of uncontrolled hernia through occipital opening. (Author's case.) Operation, undertaken in terminal stage of compression, unavailing. (Compare Fig. 69.)

one running down to the upper cervical vertebræ. These incisions make one half of the cross-bow. (Fig. 125.) According to Cushing the insertion of the superficial neck muscles (trapezius, sterno-cleido-mastoid, splenius capitis, and complexus) into the superior curved line should not be disturbed, as one is apt to do in the baring of the bone with the raspatory, inasmuch as by so doing the muscular protection from subsequent hernia is materially lessened. The skin flap, therefore, is first dissected down to just below the curved line, and the muscles cut through down to the bone, leaving a proper upper border for suturing. The muscles are then divided in the mid-line down to the occipital bone, and the flap elevated from the bone and pulled over to the side.

It is easy to bare the occipital bone completely, as far as the posterior edge of the foramen magnum. A button of bone in the centre of the exposed area, where it is thinnest, is now removed with a hand trephine; and from this opening it is an easy matter to cut away with rongeur the greater part of the occipital bone on one side. The danger points are the mastoid cells, which should not be opened for fear of infection, and certain emissary veins. The largest of these, to which Frazier has called particular attention, is the mastoid emissary, leading directly from the lateral sinus in the posterior mastoid surface. Hemorrhage from this vein, which may be of unusual size, has proved fatal. Other

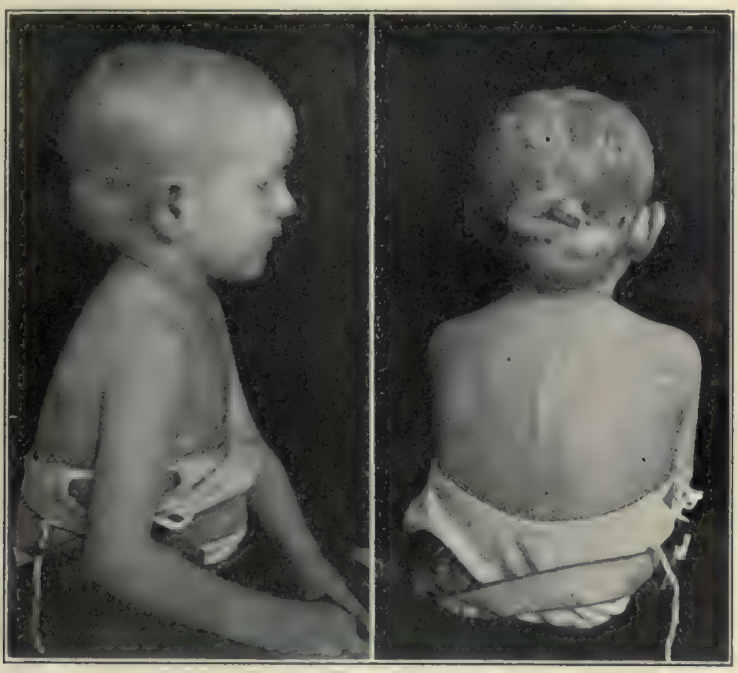

Fig. 124.—Photographs Showing Side and Rear Views of Case Represented in Fig. 83 (extensive basal cyst giving chiefly right cerebellar signs from subtentorial extension); illustrating protrusion of the suboccipital region by reason of exit of cerebro-spinal fluid under positive pressure through operative opening in occipital bone. Suboccipital decompression.

emissary veins are found around the external occipital protuberance; and occasionally one or two along the occipital ridge in the middle line. The latter are small, but bleeding from them may be annoying. If a Gigli saw be passed at the upper and lower limits of this middle bridge, and it be then pried off, any rupture of emissaries that may take place is left till the last, and the bleeding vessel may then be freely exposed. Upward it is well to expose the lateral sinus, which is one's guide to the roof of the posterior fossa. Downward one may go into the foramen magnum, but must be prepared to stop bleeding from the small marginal sinus.

The dura is then opened in horse-shoe shape and turned down, and the cerebellum explored. If decompression is decided on, the dura is to be cut away. In any case, the writer believes in leaving it open, save where very little damage has been done, as in the evacuation of a cyst, in order to avoid any retention of reactionary exudation which might prove serious by pressure on the near-by

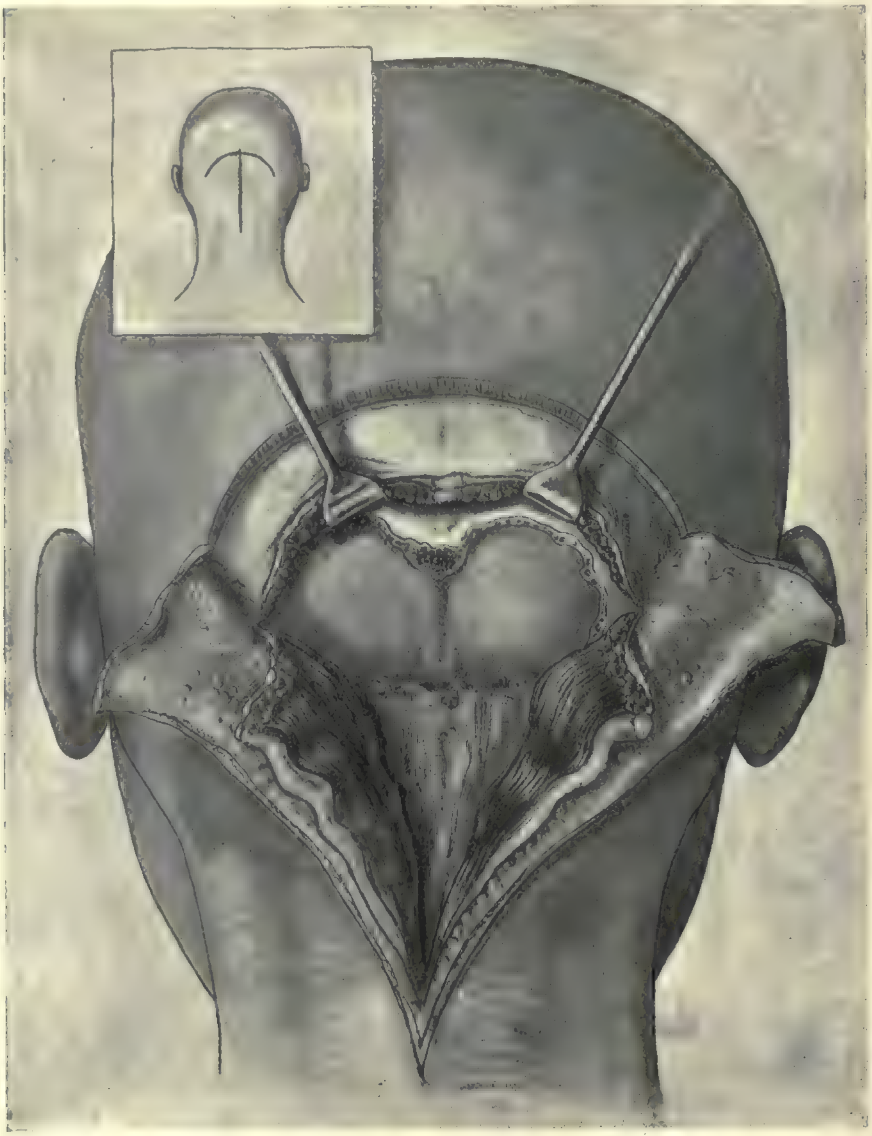

Fig. 125.—Sketch of the Field of Operation before Opening the Dura, in the Suboccipital Procedure. Note the high transverse cut of the "crossbow" incision. (Cushing, *loc. cit.*)

medulla, and to provide for escape into the soft tissues of the scalp according to the principle of subcutaneous drainage as opposed to external drainage. The wound should then be closed in layers, and always without a drain, the skin being stitched very accurately.

Hernia Cerebri.—Hernia cerebri is a common complication following the operative removal of tumors, and may so enter as the result of any process which materially reduces the intracranial space if an opening be made in the cerebral casing. Leonard Hill and Cushing have drawn attention to the hernia of the brain stem that occurs into the foramen magnum, whereby the tonsils of the cerebellum with the medulla become more or less indented; and it is not unusual, as I have seen at post-mortem examinations, to find very clear evidence of this fact in such conditions as hydrocephalus and tumor. The protrusion of the cerebral substance that occurs when an operative or accidental opening is made in the skull under conditions of tension or infection constitutes true hernia cerebri.

The cause is often tumor. If the latter be malignant and destroy the bone, hernia cerebri may be spontaneous; more often it follows exploratory operation which has failed in its object of removal. Another common cause is the hydrocephalus which complicates many lesions, tumor and the various forms of meningitis in particular. Another cause is the hemorrhage and the widespread œdema following traumatism. Most frequent of all perhaps is infection. The work of Alice Profé* upon the causes of hernia cerebri as a complication of tumors, showed that the trouble was due to infection in the vast majority of cases.

Where operation for tumor has been misdirected and the tumor is not found, lack of relief of tension may force the brain through the opening to such an extent that it may be impossible to replace the bone, or even, under rare circumstances, to cover it with the scalp tissues alone. Under these circumstances various procedures have been recommended. It has been advised to cut off the protruding mass, but this is now less favorably regarded; instead, ventricular puncture is said to relieve tension sufficiently to allow of replacement. Cushing has advised lumbar puncture in such instances, and tells us that there is no danger in this procedure once the skull is opened widely; he assures us also that it is practically always sufficient to accomplish the purpose. The writer has found, in one intermusculo-temporal decompression in the terminal hydrocephalic stage of a probable tumor, that neither an exceedingly wide bone opening, nor ventricular puncture, nor finally the addition of lumbar puncture was sufficient to reduce the hernia so that it could be covered by the temporal fascia; ultimately it was covered, in its upper part, by scalp alone.

It should be remembered that brain protrusion is the natural result of the safety-valve operation, and should be expected as being the natural means of relief. The important indications are, first, to avoid infection and, second, to make the bone opening, where possible, over a silent region, so that, when hernia does occur, the inevitable loss of function of the extruded brain may be of no special moment. To fulfil the first indication it is necessary to provide the bar-

* Alice Profé, in "Bibliotheca Med.," Abth. D, I, Heft 7, Stuttgart, 1903.

rier afforded by a thoroughly closed incision; infection does not enter through a well-stitched skin without drain. For the control of hernia one must have, in addition to skin, a layer of muscle. There can be no doubt that Cushing's split-muscle operation in the temporal region, and Frazier's similar procedure in the sub-occipital region, mark a decided advance in guarding against the unpleasant effect of uncontrolled hernia cerebri in decompressing operations.

If sepsis has already entered in, the wound should be opened; one can do but little in this condition. The common result is a fatal spreading suppurative meningitis. Certainly, as soon as infection is diagnosed, the bone opening should be made wider and the neighborhood between brain and dura mater packed as recommended by Witzel. Probably the brain will continue to extrude itself for some time, and must be removed *pari passu* with this extrusion. There are a few instances on record of infections overcome and of great loss of brain substance without permanent damage to cerebral function.

SURGERY OF THE CRANIAL NERVES.

By CHARLES H. FRAZIER, M.D., Philadelphia, Pa.

THE surgeon should be familiar with the function and distribution of all the cranial nerves. In many instances he must draw upon his knowledge of the function of the cranial nerves in order to establish a diagnosis of a lesion of the cranium and cranial contents which may call for surgical interference. In many instances he may be called upon to operate for the relief of symptoms which may be due to lesions of the nerves themselves or of tissues adjacent to them. To cover systematically the surgical aspects of the cranial nerves, they will be considered individually.

I. **The Olfactory Nerve** (*N. olfactorius*).—The function of this nerve may be partially or completely arrested in punctured wounds, in fractures of the skull, and in intracranial hemorrhage. In punctured or gunshot wounds, one or both olfactory bulbs may be severed and the sense of smell be partially or entirely lost. In fracture of the anterior fossa of the base of the skull involving the cribriform plate, anosmia is not an infrequent symptom. In most cases the functional disturbance is only transitory and is due to the pressure of extravasated blood. If the nerve fibres have been torn off from the optic bulb as they pass through the foramina, anosmia will be permanent. Basilar meningitis may indirectly, by the pressure of the exudate, or directly, by secondary involvement of the nerve itself, lead to functional disturbances; likewise, tumors, either directly or indirectly, may interfere with the function of the nerve. A tumor of the anterior fossa, by continued pressure, may cause atrophy of the nerve. It is supposed, however, that internal hydrocephalus and tumors of either the cerebrum or the cerebellum may cause an olfactory neuritis, analogous to the more common optic neuritis.

II. **The Optic Nerve** (*N. opticus*).—The visual disturbances will depend upon whether the nerve, the chiasm, or the optic tract, is involved. As with the olfactory nerve, punctured or gunshot wounds, fracture, and blood extravasations may disturb the integrity of the nerve. The nerve is occasionally involved in fractures of the anterior fossa, especially in fractures of the roof of the orbit. Pressure may be exerted upon the nerve by encroachment upon the foramen or by the projection of a spicule of bone. In a case recently under the care of the author, a fracture of the skull was followed by complete optic atrophy which could be accounted for only in this way. The pressure of a hemorrhagic exudate upon the chiasm is likely to cause temporary visual disturbances, while in extravasation into the sheath of the nerve the prognosis is much more unfavorable. In the list of the conditions which by direct pressure may interfere with the function of the nerve, should be included aneurysms of the ophthalmic or the internal carotid artery, tumors of the base of the skull and especially of the pituitary body, tuberculomata and gummata, and leontiasis ossea. In an analysis of thirty-four cases of leontiasis ossea Kanavel found in ten a varying degree of optic neuritis. This condition may be relieved or prevented by removing as much of the new bony growth as encroaches upon the orbital contents and optic foramen.

The general consideration of optic neuritis and choked disc, or papillœdema, should be left to a treatise on ophthalmology, but reference may be made here with propriety to one or two phases of the subject. Conditions giving rise to increased intracranial tension frequently cause brain-tumor papillitis (Gunn) or papillœdema (Parsons). It has long been recognized as a symptom of tumor, abscess, or internal hydrocephalus. The surgeon must bear in mind, however, that any traumatic lesion which causes increased intracranial tension may have the same effect upon the nerve. In such conditions as cerebral hemorrhage or cerebral contusion with œdema, the presence of choked disc may give some clue as to the degree of intracranial tension and suggest the propriety of hastily adopting some means of relieving pressure. Care must be exercised in distinguishing a papillœdema from a hyperopic neuritis. de Schweinitz believes that, in some cases of reported engorgement œdema of the papilla after intracranial injuries, the observer has been deceived by the presence of a hyperopic neuritis, which he mistook for a beginning engorgement œdema supposedly due to increased intracranial tension.

Since the introduction and popularization of the decompressive operation, papillœdema or choked disc, as a manifestation of brain tumor, has assumed an important surgical aspect. Moderate grades of this occur in eighty per cent of brain-tumor cases, and, whatever theory as to its development may prove true, we have in the decompressive operation a most valuable therapeutic measure. It is important to bear in mind that it does not always develop with the same rapidity, that the degree of papillœdema has no constant relation to the size of the tumor, that if not relieved it will inevitably lead to permanent blindness, and that, by the performance of an operation easy of execution and comparatively free from danger, the neuritis may subside and vision be restored. Unreasonable delay in recommending operation in suspected cases of brain tumor, once the papillœdema makes itself manifest, should be regarded as inexcusable.

III., IV., and VI. **Oculomotor Nerve, Trochlear Nerve, and Abducens Nerve** (*NN. oculomotorius, trochlearis, and abducens*).—Because of their proximity to one another as they traverse the middle fossa of the skull and pass out through the orbital fissure, these nerves may be considered together. Although, after serious trauma to the skull or its contents, all these nerves may be injured, as a rule but one or two of the group are involved. Probably because of its extended course within the skull and its relation to the petrous bone the abducens is more frequently injured than either of the other two; next in frequency is the oculomotor; while the trochlear is rarely paralyzed alone. Inequality of the pupils is a valuable sign in differentiating between lesions of one or the other side of the brain. In cases of hemorrhage, however, the pupillary manifestations are by no means constant. Thus, in a series of 70 cases (Enderlin: *Deutsche Zeitschrift für Chirurgie*, Bd. LXXXV., p. 165) both pupils were dilated in 39, in 7 they were markedly contracted, and in 20 there was unilateral dilatation on the affected side.

The pathological processes which by pressure or infiltration involve the first and second cranial nerves may also affect the third, fourth, and sixth. They comprise aneurysms, tumors (including those of the pituitary body), abscess, internal hydrocephalus, tuberculosis, syphilitic deposits, and, in addition, thrombosis of the cavernous sinus. Paralysis of the ocular nerves is one of the most common symptoms of basilar meningitis and causes alteration in the size of the pupils or in the movements of the eyeballs, more especially strabismus, inequality of the pupils, and moderate ptosis. Owing to the proximity of these nerves to the ganglion of Gasser, one or all three, particularly the abducens, have been injured in the extraction of the ganglion.

V. **Trigeminal Nerve** (*N. trigeminus*).—Involvement of the trigeminal nerve may be revealed by partial or complete paralysis of the muscles of mastication, by partial or complete anæsthesia, or by pain in the distribution of one or all of its branches. Isolated paralysis of the motor fibres is so rare that our interest centres in its sensory distribution. In hemorrhages, fractures, and tumors of the posterior fossa, more especially in the cerebello-pontile angle, we may have hyperæsthesia, anæsthesia, or more frequently hypæsthesia from pressure upon the sensory root as it passes over the apex of the petrous bone to reach the ganglion. Fractures or hemorrhages of the middle fossa may involve the ganglion, or, as is more frequently the case, one or more of its branches, as they pass through their respective foramina, as in Kroenlein's case where two branches of the fifth, together with the abducens, were involved. Tumors of the base of the brain or skull and tumors of the ganglion itself may cause a neuralgia severe enough to warrant surgical intervention. From the standpoint of diagnosis the above lesions are of some practical significance, but the surgeon's main interest in the trigeminal nerve lies in the fact that he is so frequently called upon to operate for the relief of *trigeminal neuralgia*.

Trigeminal Neuralgia.—Preliminary to a consideration of the surgical aspects of trigeminal neuralgia a brief statement may be appropriately made as to the varieties, pathology, and symptomatology of this affection. For practical purposes we recognize two types—the minor neuralgias and the major or epileptiform neuralgias. The minor neuralgias usually have some demonstrable cause, whether it be caries of the teeth, herpes, inflammation of the sinuses, or some constitutional disease such as chronic nephritis, malaria, lead poisoning, syphilis, gout, or rheumatism. In the minor neuralgias the pain is not so intense, but more or less continuous; it is not of the same paroxysmal character, with periods of intermission, when for a considerable time the patient is entirely free from pain. The minor neuralgias are usually due to some peripheral lesions, upon the recognition and treatment of which the symptoms will usually subside. Major or epileptiform neuralgia is in all probability, in many instances, of central origin; that is to say, it originates in the ganglion, although unquestionably it begins in some instances as a peripheral lesion, and the ganglion is involved secondarily. The major type is characterized by the paroxysmal outbursts; by the tendency manifested by the attacks to recur, and by the fact that they become progressively more frequent, more severe, and finally unbearable; by the associated facial tic; and by the hopelessness of treatment other than operative. If we exclude those cases in which there is a tumor of the ganglion, either primary or secondary, there is some dispute as to whether there exists, in the Gasserian ganglion, any demonstrable pathological lesion which could be held accountable for trigeminal neuralgia. Spiller, who probably has had more opportunities for examining ganglia than any other individual observer, says, in a comparatively recent contribution (Keen's "Surgery," Vol. II., page 675): "Much caution is needed in ascribing tic douloureux to cellular changes in the Gasserian ganglion. This has been recently emphasized by Rocco Caminiti (*Archiv für klin. Chir.*, LXXVII., 4), and, although he is in error when he says that not more than twenty examinations of excised ganglia have been made, his conclusions seem to be justified. For example, my own investigations (*Am. Jour. of Med. Sci.*, Nov., 1898) on seven Gasserian ganglia, although reported (1898) some years in advance of his paper, have been overlooked, and he includes only the report of two ganglia, and of one case of endothelioma of the ganglion reported later. Inasmuch as comparatively few Gasserian ganglia have been examined, although many have been removed, it cannot be said that cellular changes are constant in tic douloureux. They are not constant even in cases in which examination has been made, and, when found, they are not the same in every instance. Caminiti points out that similar cellular changes are present when tic douloureux has not existed, and that in certain cases of tic the cause has been found in a tumor of the pons, in an aneurysm of the carotid, or in a tumor of the brain causing pressure upon the ganglion. It would hardly be expected that the sole cause would be found in cellular changes within the ganglion, nor has it been demonstrated that it is always to be sought in the ganglion. The peripheral branches may first be diseased, and the cellular changes may be secondary to, and produced by, these peripheral alterations—a reaction at distance. The peripheral nerve fibre and cell body are a unit, and one cannot be degenerated for a long time without producing change in the other." Spiller has found the vessels exceedingly sclerotic and the medullary sheaths much swollen; there may be no axis cylinder, or the latter may be irregular and appear as separate masses of hyaline substance. The nerve sheaths may be empty or the nerve fibres much atrophied. Hutchinson regards it as improbable that typical epileptiform neuralgia depends upon a true neuritis; Krause's observations, both of the peripheral nerves and of the ganglia, have been negative.

Symptomatology.—As has been already said, neuralgia minor is usually due to some peripheral irritation or to some systemic disturbance. The distribution of the pain will depend upon the seat of the irritating focus. Thus, if secondary to a carious tooth of the lower jaw, the pain will be referred to the distribution of the inferior dental; if dependent upon inflammation of the frontal sinus, the pain will be referred to the distribution of the first division. Pain is often more or less continuous, although associated at times with paroxysms and aggravated by local conditions such as cold and by the depressing effect of mental anxiety and of physical and mental fatigue. Except during the paroxysms, points of tenderness will be found over the affected nerve. When the first division is involved, the "tender points" will be found at the supraorbital notch, in the outer part of the upper eyelid, and at the emergence of the nasal branch at the lower edge of the nasal bone. The pain radiates over the anterior half of the head, to the eyelid and even to the eye itself, and to half of the nose. The second division of the trifacial nerve gives off a few branches as it traverses the spheno-maxillary fossa and appears at the infraorbital foramen as the infraorbital nerve, and at this point it divides into the palpebral, nasal, and labial branches. When this division is involved, the "tender points" will be found at the infraorbital foramen, at the side of the nose, and over the most prominent portions of the malar bone. If the dental branches are involved pain will be referred also to the teeth and gums of the upper jaw. Finally, if the third division of the nerve is involved, pain will be referred to the distribution of one or all of its sensory branches—to the parietal eminence, the temple, and the external ear (temporal branch and auriculo-temporal branch), to the tongue (lingual), to the gum and teeth of the lower jaw (inferior dental branch), and to the lower lip (mental branch). The tender points are at the inferior dental foramen, where the auriculo-temporal crosses the zygoma, over the parietal eminence, in the tongue, and at the mental foramen.

Surgical Treatment of Trifacial Neuralgia.—Before undertaking an operation, or even before considering the question of operation, each case should be carefully investigated in order to determine whether the neuralgia is due to any constitutional disturbance, such as gout, etc., or to some focus of irritation, such as a carious tooth, inflammation of the sinuses, or iritis. To this class belong the minor neuralgias which will usually respond to treatment directed, on the one hand, to the correction of the systemic disturbance and, on the other, to the removal of the source of irritation. If these measures fail, recourse to operation will be necessary. The operative treatment of neuralgia, therefore, is applicable chiefly to the major neuralgias, in which there may be no demonstrable lesion, peripheral or otherwise, to account for the pain. For this class one must choose between the extracranial and the intracranial operation. It is difficult to lay down any hard and fast rule applicable to all cases. Suffice it to say that preference should be given the extracranial operation on the peripheral nerves unless there is some very positive indication for the intracranial operation. This general principle should be observed chiefly because the peripheral is a minor operation, practically devoid of risk, while the central operation may be fatal in one out of every twenty cases; and this advice still holds good notwithstanding the fact that there will be a certain percentage of recurrences after the former, while the latter practically insures permanent relief. The peripheral operation is suitable chiefly in the early stages of the disease when only one, or perhaps two, of the branches are the seat of referred pain; when the attacks recur only at long intervals and are neither of long duration nor excessively severe; and when the patient's condition is such as to contraindicate any major operation.

On the other hand, when peripheral operations have failed or have been followed by recurrence; when we are dealing with a case of great intensity and long duration; when, in order to include all the branches involved, particularly of the maxillary division, it would be necessary to resect the nerves close to their emergence from the skull; and, finally, when at least two, if not three, divisions are involved, there should be no hesitation in recommending the central operation. Neither the intracranial nor the extracranial operation should be practised, to the exclusion of the other; each one has its place and its indications. With this brief consideration of the general surgical aspects we may proceed to a description of the various operative procedures.

Extracranial Operations upon the Trigeminal Nerve.

General Remarks.—Extracranial operations include those which attack the ramifications of the nerve at their exit from the skull and the so-called "peripheral" operation. At one time it was thought sufficient simply to expose and divide the nerve, but, owing to the tendency of the nerve to undergo regeneration, recurrences were frequent. A properly executed peripheral operation implies the removal, by excision or avulsion (neurexeresis), of a considerable section of the nerve. The longer the section removed the less the likelihood of regeneration and therefore of recurrence of the neuralgia. There is no question as to the superiority of avulsion over resection. Avulsion or neurexeresis was proposed first by Thiersch. The nerve is grasped with a pair of forceps, obliquely to its long axis; the closed instrument is twisted on its own axis slowly, at the rate of one half turn per thirty seconds. For this purpose Thiersch recommends a pair of forceps so constructed that the blades do not cut through the nerve fibres. One blade of the forceps is concave, the other convex, and both are ribbed transversely or longitudinally, and have blunt edges. By this method not only will a considerable portion of the peripheral segment with its fine terminal filaments be extracted, but also the central segment up to the ganglion. (See Fig. 126.) The advantage of the Thiersch operation over resection is twofold: first, it is possible by this operation to extract a considerably longer section of the nerve; and, second, forcible extraction, according to van Gehuchten, will be followed by degeneration not only up to the ganglion cells, but even into the bulbo-spinal root. The relief afforded by the Thiersch operation is of longer duration than that which is obtainable by any other method. A number of cases have been reported (Rose, in *The Practitioner*, March, 1899) in which there has been no recurrence five or six years after the operation.

I. Ophthalmic Division of the Trifacial Nerve.—Of its three branches the frontal and nasal are the only ones that require consideration.

a. Frontal Branch (N. frontalis).—About the middle of the orbit the frontal nerve divides into its terminal branches, the supraorbital and the supratrochlear. Both leave the orbit through the supraorbital notch. To expose them, an incision, two centimetres long, is made at equal distances on either side of the supraorbital notch, following the direction of the eyebrow. After the skin and the fibres of the orbicularis palpebrarum have been divided, an incision is made into the periosteum in a direction parallel to the supraorbital ridge. (Fig. 127.) The supraorbital artery and nerve will be exposed in the supraorbital notch. The artery may be ligated, if necessary, and the nerve traced along the roof of

FIG. 126.—Specimens Removed by the Thiersch Method. 1. Specimen to the left, the infra-orbital nerve; 2, specimen in centre, the infra-orbital nerve; note the fact that one of the superior dental branches has been extracted with the trunk; 3, specimen to the right, inferior dental and mental branches. This nerve was removed in two sections, through two incisions; the distal portion from an incision at the mental foramen, the central portion from an exposure of the nerve at the angle of the the jaw. (Original.)

the orbit beneath the periosteum until the frontal branch is reached midway between the points where it divides into the supraorbital and the supratrochlear nerves. The nerve trunk is grasped with Thiersch forceps and extracted. The wound in the muscle is closed with catgut sutures and the skin with a subcuticular suture. It should be remembered that in some cases there may be no supraorbital notch, but a foramen through which the nerve reaches the surface a short distance above the margin of the supraorbital ridge. Unless one bears this in mind, unnecessary time may be consumed in searching for a landmark which may not exist.

b. Nasal Branch (N. nasociliaris).—This nerve is accessible at the point where it passes into the anterior ethmoidal foramen to enter the cranial cavity. It may be exposed by extending the incision described above somewhat farther toward the median line, and will be found about two centimetres from the edge of the supraorbital ridge, on the inner aspect of the wall of the orbit. In the great majority of those cases in which the ophthalmic division is involved, pain is referred only to the distribution of the supraorbital nerve, so that it is usually only necessary to avulse the supraorbital branch. If, however, pain is referred to the inner or the outer surface of the nose the nasal branch must also be removed.

Fig. 127.—Incisions for Exposure of the Infra- and Supra-orbital Nerves (Nn. Infra-orbitalis and Supra-orbitalis). (Original.)

II. The Maxillary Division (*N. maxillaris*).—The second or maxillary division of the trifacial nerve, and particularly its infraorbital branch, is more frequently affected than any other division. Further subdivisions of the nerve are: Within the spheno-maxillary fossa, the spheno-palatine, the posterior superior dental, and the temporo-malar branches; in the infraorbital canal, the middle inferior and superior dental branches; and in the face, the infraorbital nerve with its three terminal branches—the inferior palpebral, the lateral nasal, and the superior labial. If pain is distributed to the terminal branches alone, the infraorbital nerve should be avulsed by the Thiersch method; if it extends to the distribution of the middle inferior and superior dental nerves in addition, it will be necessary to remove that portion of the infraorbital nerve which lies as far back as the fissure; and, if it involves the nerves given off from the spheno-palatine (Meckel's) ganglion, the maxillary division must be exposed and divided at the base of the skull, at the point where it makes its exit from the foramen rotundum.

a. Infraorbital Nerve.—This nerve may be exposed, by the intra-buccal or the extra-buccal incision, at the point where it emerges from the infraorbital foramen. This foramen is situated one centimetre below the inferior margin of the orbit, at the junction of its middle and inner thirds. A line drawn from the supra-orbital notch downward between the two lower bicuspid teeth intersects the infraorbital and mental foramina. (Keen.) To reach the nerve through the mouth, an incision is made through the mucous membrane where it is reflected from the upper lip upon the superior maxilla. The periosteum is incised and separated upward as far as the foramen. By the extra-buccal route an oblique incision two centimetres long is made through the skin and cellular tissue over, and following the direction of, the infraorbital ridge. This incision avoids those branches of the facial nerve which supply the orbicularis palpebrarum as well as the muscles below the incision. When the fibres of the levator labii superioris are divided, the nerve will be seen, in many instances, already broken up into its terminal branches. The infraorbital artery and vein, especially the latter, should be avoided, as rather troublesome hemorrhage will ensue if they are lacerated. Unless there is a positive indication that such a course should be adopted, it is not necessary to continue the dissection and expose all that portion of the nerve which lies in the infraorbital canal. If the nerve is grasped at its exit from the infraorbital foramen and slowly extracted by the Thiersch method, practically all that portion of the nerve which is contained in the canal will be removed, and not only that, but some of the dental branches as well. (See Fig. 127.) When, however, the pain in the distribution of the dental branches is a conspicuous feature, it is advisable to resect the nerve by the open method as far back as the sphenoidal fissure. To accomplish this, the periosteum is separated from the floor of the orbit, back to the infraorbital groove. The roof of the canal is so thin that it is often easily broken open with a grooved director. The nerve thus freely exposed is now grasped with forceps, and, by avulsion or with scissors, is resected back as far as the spheno-maxillary fissure.

b. Extracranial Division of the Maxillary Nerve at the Base of the Skull.—Although it may be possible to reach the descending branches (nn. palatini) of the spheno-palatine ganglion after they emerge from the posterior palatine canal, it is seldom that these branches are alone involved; when the branches given off in the spheno-maxillary fossa (including Meckel's ganglion) are involved, the other peripheral branches (in other words, the whole division) are usually implicated. In order to secure absolute relief, therefore, this division must be severed either within the cranium or at the point where it emerges from the skull. If both the second and third divisions are involved, there is no question as to the propriety of resorting to an intracranial operation; when, however, only one of these is involved, it is still a question as to whether the intracranial operation should not be resorted to, because in many respects it is less difficult and less complicated than the extracranial method. If, for any reason, the extracranial approach is preferred, the nerve may be exposed by the Kocher or the Carnochan method.

*Kocher's Operation.**—The incision is designed to avoid injury to the branches of the facial nerve, and resembles that for exposure of the infraorbital nerve. Beginning at the margin of the infraorbital foramen it extends outward in a horizontal direction, over the inferior portion of the body of the malar bone,

* Kocher's "Chirurgische Operationslehre," 1907.

to the zygoma. The facial nerve and Steno's duct both lie beneath the incision. At the inner end the incision extends down to the bone, between the lower border of the orbicularis palpebrarum and a point situated over the insertion of the levator labii superioris. The former muscle with the periosteum is dissected up toward the orbit, while the latter with the periosteum is reflected far enough to expose the infraorbital nerve as it emerges from the infraorbital foramen. (Fig. 128.) The nerve is liberated and secured with a ligature. The

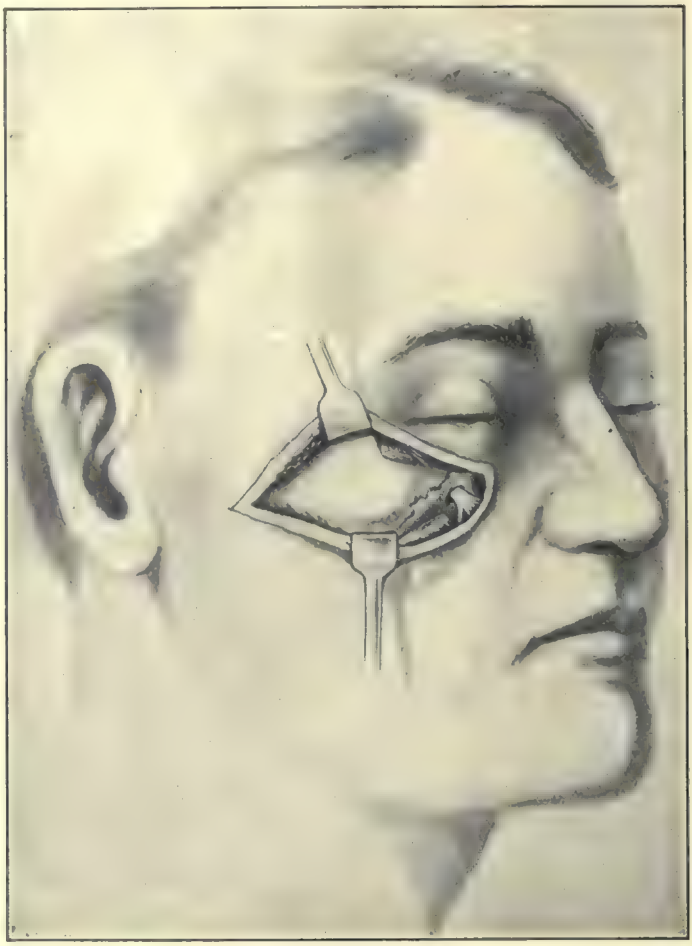

FIG. 128.—Exposure of the Superior Maxillary Nerve (N. Maxillaris), Kocher Method. (Original.)

outer end of the incision extends to the attachment of the zygomatic muscles, which, with the periosteum, are reflected upward. The anterior portion of the masseter muscle is detached from the inferior surface of the malar bone. With a periosteal elevator the malar bone, the malar process of the superior maxilla (up to the infraorbital foramen), and the floor of the orbit are laid bare. With a chisel the roof of the infraorbital canal is laid open as far as the outer end of the spheno-maxillary fissure. The malar bone is then divided with a chisel, in a direction running obliquely from the infraorbital nerve to the antrum, as far as the orbital plate. The anterior surface of the malar bone, the malar process of the superior maxilla, and the outer wall and floor of the orbit are laid bare with a periosteal elevator. To free the malar bone so that it may be dislocated, it will be necessary to sever it from its various connections along the following lines (see Fig. 129):—(1) Along the malo-maxillary suture to the outer end of the spheno-maxillary fissure, thus removing the roof of the infraorbital

Fig. 129.—Exposure of the Superior Maxillary Nerve (N. Maxillaris), Kocher Method. (Original.)

canal; (2) along the anterior surface of the malar bone from the infraorbital nerve to the anterior fibres of the masseter muscle; (3) through the lateral wall of the antrum upward, to join posteriorly the preceding line of division of the orbital plate; (4) through the fronto-malar suture to the posterior part of the spheno-maxillary fissure, so that the zygomatic crest and the orbital plate of the sphenoid may be removed at the same time; (5) through the zygoma. The malar bone is then dislocated outward with a sharp hook; the orbital contents, protected by means of a blunt retractor, are displaced upward, and the infraorbital nerve can then be traced backward to the foramen rotundum. The nerve is hooked up behind the descending branches of the spheno-palatine nerve, grasped with forceps, and avulsed by the Thiersch method. The infra-orbital artery, which is in close proximity to the nerve, may be avoided or ligated. The malar bone is then replaced, no sutures being necessary to prevent displacement, and the cutaneous wound is closed.

III. THE MANDIBULAR DIVISION (*N. mandibularis*).—According to the distribution of pain it may be necessary to avulse the trunk of the nerve at the point where it emerges from the foramen ovale, or only one of its individual branches—viz., the inferior dental, the lingual, or the auriculo-temporal.

a) *Inferior Dental Nerve* (N. alveolaris inferior).—This, the largest of the terminal branches, is, next to the infraorbital, the most frequently implicated. It may be approached by the extra-buccal or intra-buccal route. If the extra-buccal route is chosen a semicircular incision is made around the angle of the jaw. A musculo-periosteal flap, including the attachment of the masseter, is reflected upward, and a button of bone is removed, with trephine or chisel, from the middle of the ramus. The nerve is then exposed as it traverses the inferior dental canal. (Fig. 130.) As a rule, it is not possible, through this opening, to remove, with the inferior dental nerve, its mental branch. To accomplish this the latter must be exposed at the mental foramen.

FIG. 130.—Incision and Trephine Opening for Exposure of the Inferior Dental Nerve (N. Alveolaris Inferior). (Original.)

Intra-buccal Method of Reaching the Inferior Dental Nerve.—The patient's mouth being widely opened, an incision is made through mucous membrane and periosteum along the anterior margin of the ramus. The periosteum and overlying structures are separated as far backward as the lingula. The nerve is easily exposed as it enters the canal. This method, though quite as easy as the extra-buccal operation, has two disadvantages: there is greater likelihood of the wound becoming infected, and not so large a section of the nerve can be removed.

Mental Branch (*Ramus mentalis*) of the Inferior Dental Nerve.—The mental foramen is entered by an incision made along a line drawn from the supraorbital notch to a point located between the two lower bicuspid teeth. To reach the nerve, a perpendicular incision through mucous membrane and periosteum is made on a line extending from the notch between these teeth down to the mental foramen. When both the inferior dental nerve and its mental branch are affected, the latter must be exposed at the mental foramen, as it cannot be removed radically with the parent trunk.

b) *Lingual Nerve* (N. lingualis).—After passing over the deep portion of the submaxillary gland, and between the mylo-hyoid and hyo-glossus muscles, the nerve traverses the floor of the mouth to reach the tongue, just beneath the mucous membrane. It is readily felt by passing the finger from before backward along the floor of the mouth. A short longitudinal incision through the mucous membrane enables one to pick the nerve up on a hook. After the avulsion has been accomplished, the incision is closed with a catgut suture. While the nerve may be reached by an extra-buccal incision, preference should be given the intra-buccal route. The former operation is relatively more difficult and has the further disadvantage of leaving a scar.

c) *Auriculo-temporal Nerve* (N. auriculo-temporalis).—After emerging from the upper portion of the parotid gland this nerve passes over the zygoma and ascends in company with the superficial temporal artery. It may therefore readily be exposed by a vertical incision extending upward from the root of the zygoma.

Extracranial Operation upon the Mandibular Division of the Trigeminal Nerve at the Base of the Skull.—What has been said of an analogous operation upon the maxillary applies with equal force to the mandibular division. If both the second and the third divisions are involved, an intracranial operation upon the ganglion or its root is the operation of choice; if the third division alone is implicated, many will still prefer the central operation. The latter is little, if at all, more difficult, and insures against subsequent neuralgic attacks in one or the other of the three divisions. Whatever method be adopted, the extracranial operation is not unattended with difficulty, because of the contracted space in which the manipulations must be conducted, and because of the rather free and troublesome hemorrhage from the pterygoid plexus. Krause lost one of his cases as a result of uncontrollable hemorrhage from this source.

Kroenlein's Operation.—The essential features of this operation are the horizontal incision through the cheek and the resection of the coronoid process. The incision begins 1 cm. ($\frac{2}{5}$ in.) behind the angle of the mouth, extends to within a centimetre of the lobule of the ear, and includes the skin, subcutaneous tissue, and two-thirds of the masseter muscle. The attachment of the masseter muscle is separated subperiosteally from the coronoid process, and the latter is divided obliquely from above downward and retracted upward. The attachment of the temporal muscle is left undisturbed. To reach the nerve the external pterygoid muscle must be retracted upward. The important structures encountered are the internal pterygoid artery and the pterygoid plexus of veins. It may be necessary to ligate the former and to tampon the wound in order to control hemorrhage from the latter. The nerve is exposed by blunt dissection and then traced up to the foramen ovale, where it is divided or avulsed. The coronoid process is secured in place with periosteal sutures. The so-called Mikulicz extracranial method differs essentially from Kroenlein's in that the entire ramus of the jaw is temporarily resected. Objections may be raised against Kroenlein's method because of the possibility of severing the branches of the facial nerve and because of the subsequent interference in the movements of the jaw.

Kocher's Method.—Kocher's incision, which resembles that employed for his operation on the Gasserian ganglion, begins a finger's breadth behind the frontal process of the malar bone and passes obliquely downward to a point below the root of the zygoma. From this point the incision extends upward just in front of the ear, at right angles to the first. (Fig. 131.) A finger's breadth above the upper border of the zygoma the temporal fascia is divided and the zygoma is resected subperiosteally, and with the attached masseter muscle is retracted downward. From behind forward the temporal muscle, together with the periosteum, is separated from the skull, and is drawn forcibly forward by means of a blunt retractor. The periosteum and soft parts are then separated by blunt dissection from the base of the skull and displaced upward. This will expose the outer surface of the base of the pterygoid process, and behind its sharp posterior margin will be found the foramen ovale, about 3 cm. ($1\frac{1}{5}$ in.) from the anterior root of the zygoma. The internal maxillary and its branches, having been displaced downward with the soft parts, are not exposed to injury. Care must be taken to avoid the middle meningeal artery. The nerve is grasped with forceps and avulsed. If hemorrhage is free, the wound may be tamponed, and final closure with replacement of the zygoma postponed for a few days.

FIG. 131.—Incision for Exposure of the Inferior Maxillary Nerve (N. Mandibularis), Kocher Method. (Original.)

Intracranial Operations upon the Trigeminal Nerve.

Historical Notice.—Dr. J. Ewing Mears, of Philadelphia, is accredited with the first suggestion to remove the Gasserian ganglion in intractable cases of trigeminal neuralgia. Although he made this proposal in 1884, the first successful operation was performed by Rose in 1890, and repeated in 1891. Rose approached the ganglion by the pterygoid route. In the same year Horsley recorded his experience with a case in which, failing to remove the ganglion, he avulsed the sensory root, the patient dying of shock. Next to the contri-

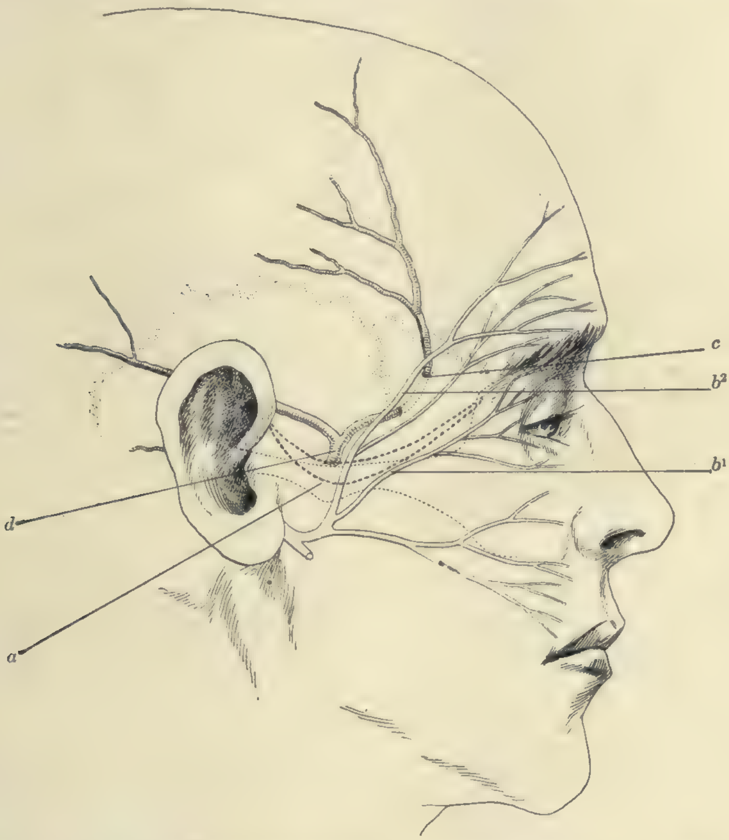

Fig. 132. -This drawing illustrates the relation of the Kocher incision to (a) the zygoma, (b^1 and b^2) the upper branches of the facial nerve, (c) that portion of the middle meningeal artery which is enclosed in a groove or canal in the parietal bone, and (d) the middle meningeal artery before its bifurcation. (Original.)

butions of Mears and Rose, the most notable were those of Hartley of New York and Krause of Altona, who, in 1892, independently the one of the other, proposed the operation now known by their names. The significant feature of the so-called Hartley-Krause operation is the temporal approach to the ganglion in contradistinction to the pterygoid route of Rose. Finally, in 1897, Poirier introduced a third method of approach—the so-called temporo-sphenoidal,—one of the essential features of which is the temporary resection of the zygoma.

From that time to the present a number of modifications of greater or less significance have been made to one or the other of the three original methods. Of those whose names have been identified with the further development of the surgery of the Gasserian ganglion should be mentioned Keen, Tiffany, Kocher, Horsley, Hutchinson, Jr., Lexer, Cushing, Quénu, Abbe, Spiller, and the writer.

Technique.—Operations upon the ganglion of Gasser and its sensory root are not the "bloody, difficult, and dangerous" operations they once were considered

FIG. 133.—This Drawing Illustrates the Relation of the (*a*) Hartley-Krause and (*b*) Lexer (infratemporal) Incisions to (*f*) the zygoma, (c^1 and c^2) the upper branches of the facial nerve, (*d*) that portion of the middle meningeal artery which is enclosed in a groove or canal in the parietal bone, and (*e*) the middle meningeal artery before its bifurcation. (Original.)

and by some are still believed to be. An intimate knowledge of the anatomical relations of the structures, familiarity with the more common variations and anomalies, the adoption of the most approved methods of controlling hemorrhage and preventing shock—these are the factors which are responsible for the reduction of the mortality from twenty-two per cent to five per cent. In experienced hands the operation is neither more difficult nor more dangerous than any other major procedures in people of advanced years, nor is it "bloody" in the sense that the patient loses a large quantity of blood.

Although many methods of exposing and removing the ganglion have been described, they differ essentially only in the method of approach, in the position and size of the opening, and in the treatment of the ganglia. Whatever may be the apparent advantages of one method over another, the individual operator will choose the one which he has found the most effective, the one by which he can carry out the operation the most expeditiously, with the lowest mortality, and with the best ultimate results. The ideal approach to the ganglion is one which does not necessitate the division of the upper branch (temporo-facial) of

FIG. 134.—This Drawing Illustrates the Relation of the Temporo-auricular Incision (Frazier) to (a) the zygoma, (b^1 and b^2) the upper branches of the facial nerve, and (c) that portion of the middle meningeal artery which is enclosed in a groove or canal in the parietal bone. (d), The middle meningeal artery before its bifurcation; (e), dotted line indicating the limits of the area throughout which the parietal bone must be removed. (Original.)

the facial nerve, one which will give an adequate exposure of the ganglion itself, without exerting too much pressure upon the brain, and, what is of minor consideration, one which avoids injury to the middle meningeal artery where it enters the groove or canal in the parietal bone. Some operators prefer the temporal route (Hartley-Krause) (Fig. 132), some the infra-temporal route (Kocher, Cushing, Lexer) (Fig. 133), others a still lower approach by the zygomatic-basal route (Quénu, Doyen), and some the auriculo-temporal approach (Frazier, Mueller). (Fig. 134.) With few exceptions the osteoplastic flap has been abandoned, as a flap composed of skin, fascia, muscle, and periosteum affords sufficient protection when the bone is permanently removed. The majority of operators favor resection of the zygoma, some temporarily, others permanently. The writer leaves the zygoma intact. A few (Friedrich, G. G. Davis) recommend preliminary ligation of the external carotid artery, and Crile temporary closure of the common carotid. By some (Lexer, Kocher, Frazier, Krause), ligation of the middle meningeal artery is resorted to as a routine procedure. The subsequent manœuvres differ somewhat in the hands of individual operators. For example, it is thought by some (Kocher, Frazier) to be unnecessary to more than avulse the sensory root, the ganglion being left intact; others remove the entire ganglion (Cushing, Lexer, Krause); others still (J. Hutchinson, Jr., Abbe) limit the interference in most cases to the lower part of the ganglion with its second and third divisions. These are the most important points of difference in the technique. Before undertaking the operation upon the ganglion or its root, the surgeon should be thoroughly familiar with the normal topographical anatomy of the structures to be exposed and of the more common variations. This knowledge should be obtained by repeated observations upon the cadaver before one undertakes to operate upon the living subject, where the difficulties of the operation are increased tenfold by the constant oozing of blood and serum.

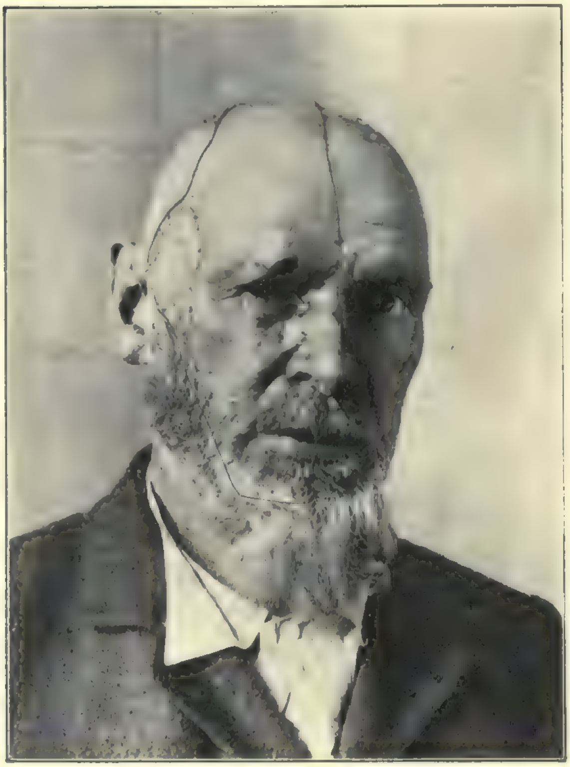

Fig. 135.—Photograph of Patient Showing Area of Anæsthesia Immediately After Division of the Sensory Root of the Trigeminal Nerve. (The photograph was taken in 1901.) (Author's case.)

With these introductory remarks I will proceed to describe, more or less in detail, a few representative methods.

Kocher's Operation.*—The patient is placed in the semierect posture, with the head hanging over the edge of the table, so that the blood and cerebrospinal fluid will not accumulate in the field of operation. The incision corresponds to that recommended for extracranial division of the mandibular or maxillary branches at the base of the skull. (Fig. 131.) After the temporal artery has been ligated, the temporal fascia, together with the periosteum, is

* Kocher's "Chirurgische Operationslehre," Fuenfte Auflage.

freed from the upper border of the zygoma, and the latter is divided at its anterior and posterior ends. The skull is trephined and the opening enlarged downward a finger's breadth from the foramina spinosum, ovale, and rotundum, and upward for a distance of 3 cm. ($1\frac{1}{5}$ in.). The dura is separated from the base of the skull until the mandibular division of the nerve is reached; over this latter the dura propria is divided and dissected backward, with a blunt dissector, from the upper surface of the ganglion. The middle meningeal artery is put on the stretch by elevating the dura, and ligated. When the posterior aspect of the ganglion is well exposed, the sensory root is picked up on a hook, grasped with forceps and slowly avulsed. (Kocher has not seen a case of recurrence after avulsion of the sensory root.)

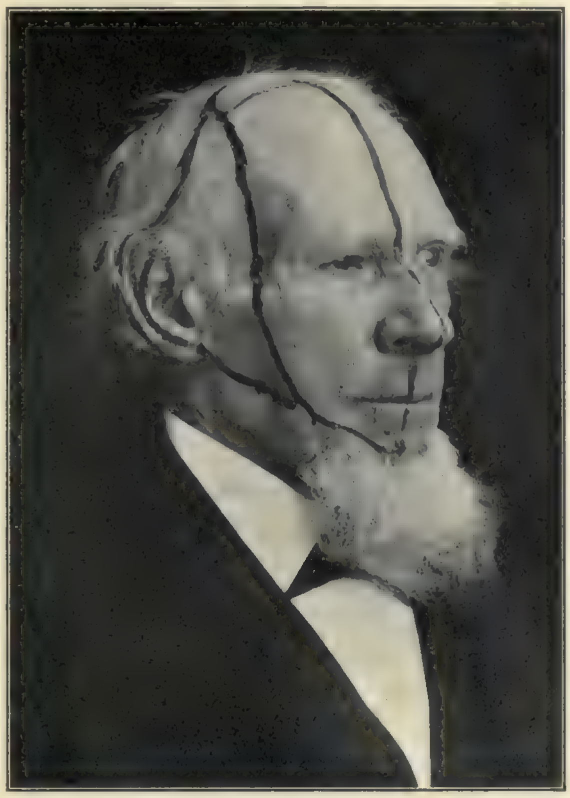

Fig. 136.—Photograph of the Same Patient (Fig. 135) Taken in 1908. Region outlined just in front of the ear is only hypæsthetic; the remainder is absolutely anæsthetic.

If the operator chooses, he may proceed then—after dividing the third, second, and first divisions—to remove the ganglion. On account of the numerous venous channels situated beneath the ganglion, this stage of the operation is attended with free hemorrhage and always requires the introduction of a tampon.

Cushing's and Lexer's Methods (Infra-temporal Route).—The ganglion is approached by the infra-temporal route. The incision differs from that of Hartley and Krause in that it does not extend so high and is fashioned in such a manner as to avoid as far as possible the branches of the facial nerve. The posterior end of the incision terminates a finger's breadth in front of the ear over the root of the zygoma. The anterior limb of Lexer's incision terminates just behind the frontal process of the malar bone. The anterior limb of Cushing's incision is still shorter. Lexer resects the zygoma temporarily; Cushing removes it. The muscles and periosteum are separated from the under surface of the great wing of the sphenoid as far as the infra-temporal crest. With chisel or fraise an opening is made in the skull just above the infra-temporal crest, and this opening is enlarged forward, backward, and downward almost as far as the foramen ovale. The upper margin of the opening is below the point where the middle meningeal artery enters its groove or canal in the parietal bone. Thus bleeding from this source is avoided. The dura is then freed from the base of the skull till the foramina are exposed. Lexer ligates the middle meningeal artery; Cushing does not. The dura propria is divided over the second and third divisions and the intervening space, and dissected backward from the upper surface of the ganglion as far as the sensory root. Cushing liberates the ganglion with a blunt dissector, freeing first the second and third divisions, then the superior and internal borders of the sensory root, and finally the first division. The ganglion is now freed from its bed, and the second, third, and first divisions divided in the order named. There remains only the sensory root, which is extracted with the ganglion.

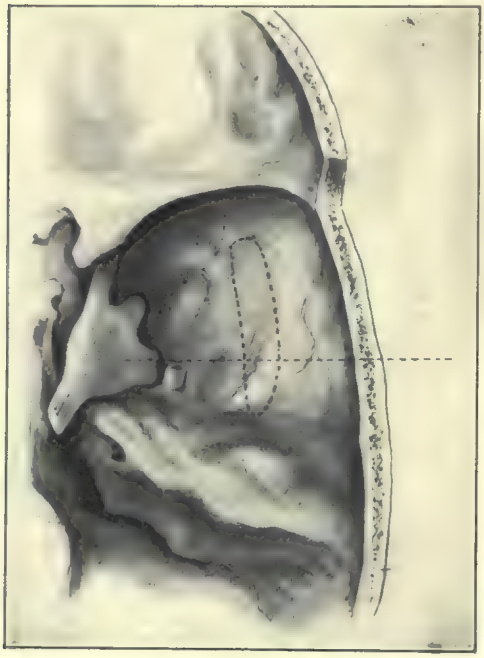

Fig. 137.—An Exact Anatomical Drawing of the Middle Cerebral Fossa, bounded in front (top of the picture) by the lesser wing of the sphenoid and behind by the petrous process of the temporal bone. The area outlined with dotted lines represents the position of the opening in the skull through which the ganglion of Gasser is approached. The line drawn perpendicular to the long axis of the skull shows the direction in which the author approaches the ganglion through his posterior incision. *This is the shortest distance from the margin of the skull to the posterior portion of the ganglion and its sensory root.* The relative positions of the middle meningeal artery and the ganglion are shown, and the desirability of ligating the vessel in order to have free access to the sensory root is manifest. (Original.)

Spiller-Frazier Method (Division of the Sensory Root by the Auriculo-temporal Route).—This operation differs essentially from all others in that no attempt is made to remove the ganglion. Division of the sensory root—or, as van Gehuchten terms it, "physiological extirpation of the ganglion"—was first proposed by Spiller. The method has been employed almost exclusively at the Hospital of the University of Pennsylvania since 1901, and with most satisfactory results. There has been no evidence of regeneration of the sensory root. (Figs. 135 and 136.) The advantages of this operation over extirpation of the ganglion may be summed up as follows: (1) It is easier of execution; (2) it is attended with less hemorrhage because the ganglion is not raised from its bed; (3) it does not expose the adjacent structures, especially the cavernous sinus and the abducens, to injury; (4) it permits the preservation of the motor root and consequently a continuation of the function of the muscles of mastication; (5) it involves a diminished risk of keratitis. The method of approach might be described as the auriculo-temporal in contradistinction to the temporal or infra-temporal method. (Fig. 134.) The incision leaves undisturbed the upper branch of the facial nerve, and the opening made in the skull is somewhat posterior (auriculo-temporal) (Fig. 137) to the usual temporal opening, and affords the most direct approach from the cutaneous surface to the posterior aspects of the ganglion. The sitting posture (Fig. 138) is preferred as the best means of controlling hemorrhage; hemorrhage may be further controlled by the use of small, properly introduced tampons, which may, if it seems necessary, be wrung out in water that is almost boiling. As a rule, it will not be necessary to drain the wound, which is closed with tier sutures.

The instruments required are a scalpel, 4 hæmostats, 1 hook retractor, 1 pair of scissors (with blunt points curved on the flat), 1 pair of tissue forceps,

FIG. 138.—Photograph of Patient in Semi-erect Posture. The position of the flap for exposure of the Gasserian ganglion and the position of the zygoma are outlined on the scalp and the cheek. (Original.)

1 author's aneurysm needle, 1 author's blunt hook, 1 burr or chisel, and 1 rongeur forceps.

Twenty minutes before the anæsthetic is administered, a hypodermic injection of morphine sulphate (gr. $\frac{1}{6}$) and atropine sulphate (gr. $\frac{1}{100}$) is made. With the patient in the vertical posture (Fig. 139) and under nitrous-oxide-ether anæsthesia, a horseshoe incision is made, beginning about the middle of the zygoma and terminating behind and a little below the apex of the helix of the ear. The musculo-cutaneous flap is made purposely a little larger than the opening in the skull. Upon reflection of the musculo-cutaneous flap a small opening is made with a burr in the underlying bone and, with rongeur forceps, the opening is enlarged downward as far as the infratemporal crest. The diameter of the opening need not exceed 3 cm. ($1\frac{1}{5}$ in.). With the handle of the scalpel the dura is separated from the skull down to the foramen spinosum. The middle meningeal artery is ligated (Fig. 141) and the dura propria is incised directly over the third division, at the margin of the foramen ovale, and separated from the upper surface of the posterior portion of the ganglion as far back as the sensory root. The latter is picked up (Fig. 142), grasped with forceps, and either divided or avulsed.

HUTCHINSON'S AND ABBE'S MODIFICATION OF THE INTRACRANIAL OPERATION.—Unless the first division is involved, J. Hutchinson, Jr., removes only the posterior two-thirds of the ganglion after dividing the second and third

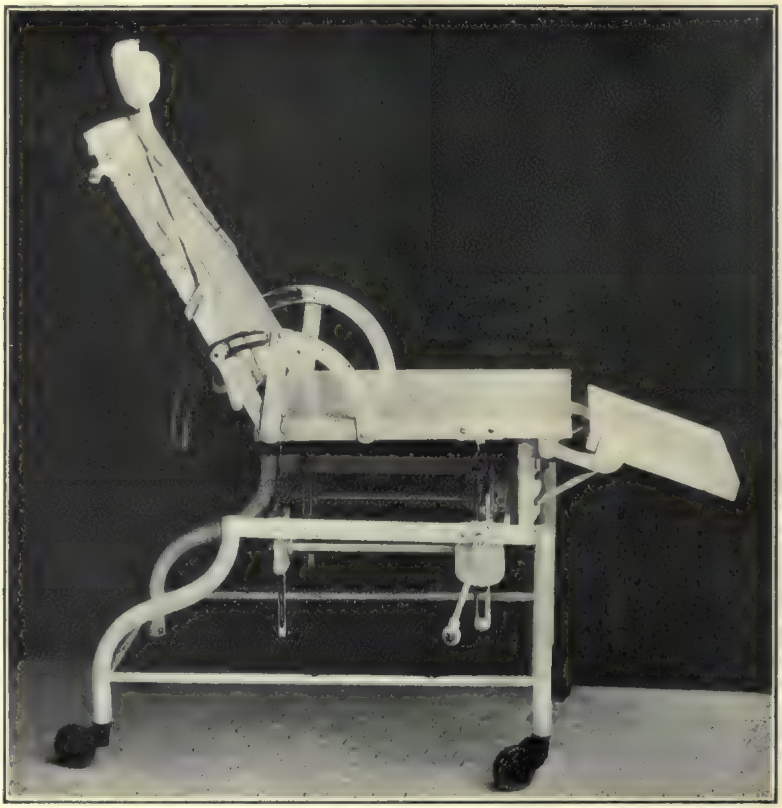

FIG. 139.—Special Operating-table for Craniotomies, Operations on the Gasserian Ganglion, etc. The position of the patient is easily changed from the reclining to the erect. The level of the stage may be adjusted to suit the operator's convenience. The author's special head-rest is attached.

branches. He contends that, in the majority of cases, the removal of the entire ganglion is unnecessary and only increases the dangers of the operation and the chances of injuring adjacent structures. For this operation the following advantages are claimed: (1) It does not produce anæsthesia of the cornea and hence there is no risk of loss of the eye; (2) it should not involve any danger of injuring the ocular nerves nor of injuring the cavernous sinus; and (3) it calls for less severe operative measures, and, besides, the accompanying loss of blood is smaller, and the pressure exerted on the brain is likely to be materially less, than in any of the other operations.

Abbe, in 1903, further simplified the operation by suggesting that interference with the ganglion be limited to intracranial division of the second and third branches, with the interposition of rubber tissue to prevent reunion of nerves to the ganglion. He has been able to obtain sufficient exposure of the structures through a vertical incision.

Immediate Results of the Intracranial Operation for Trigeminal Neuralgia, and the Mortality.—Tiffany's table of 108 cases with a mortality of 22 per cent is frequently quoted in modern writings. Such a statement gives the readers a very erroneous impression of the advances which have been made in the field of surgery. The largest individual series is that of Sir Victor Horsley, who in 1905 had performed 120 Hartley-Krause operations with only 4 deaths as a direct result of the operation (mortality 3.3 per cent). If we combine

Fig. 140.—Photograph of Patient in Vertical Posture, with shoulders and chest covered with rubber cape to prevent saturation of clothing during the operation. (Original.)

the Horsley figures with the operative experience of a few others—as, for example, Hutchinson, Lexer, Cushing, Lloyd, Doellinger, and the writer—we have a total of 230 cases with a mortality of 3.7 per cent. This is a very fair estimate of the risk of the operative treatment of trigeminal neuralgia at the present day. Even were the minimum mortality 5 per cent the operative risk would compare very favorably with that of any other major operative procedure performed on a class of patients whose average age is between 50 and 60, not a few being over 70 years of age. To say that the removal of the Gasserian ganglion is a "bloody, difficult, and dangerous operation" and "usually cures the pain if the patient survives" conveys to the casual and otherwise uninformed reader an absolutely erroneous impression. In the majority of fatal cases death has been due to infection, hemorrhage, cerebral trauma, or shock.

In a series of sixteen fatal cases selected by J. Hutchinson, Jr., the largest number (7) died as a result of hemorrhage or shock, and most of these within the first twenty-four hours; the second largest number died of sepsis, from seven days to three months after the operation; two died of hemiplegia; and, in one case, death was attributed to a fatty heart. If proper precautions are

FIG. 141.—Author's Method of Approaching the Sensory Root of the Trigeminal Nerve. The ligature has been passed around the middle meningeal artery preliminary to ligation. A pair of curved scissors is used for retraction. (Original.)

taken to prevent excessive bleeding—such, for example, as the vertical posture, intelligent tamponing of the wound throughout the operation, ligation of the middle meningeal artery, and protection of the cavernous sinus—the amount of blood lost should not affect the outcome of the operation. If hemorrhage is reduced to a minimum, if the patient is protected from exposure to cold, if the anæsthetic is competently administered, and if in suitable cases the operation is divided into two stages, shock should play no part as a factor in the mortality. With the most stringent observance of the principles of aseptic technique the risk of sepsis is reduced to a minimum. It should be remembered, however, that the chances of sepsis are increased fourfold if the operation is performed in two stages. This is usually resorted to in cases of troublesome hemorrhage; a large tampon being introduced and allowed to

Fig. 142.—Author's Method of Dividing the Sensory Root of the Trigeminal Nerve. The middle meningeal artery has been divided distal to the ligature. Only the posterior aspect of the ganglion has been exposed, and a small blunt hook has been passed around the sensory root. The latter occupies a position near the middle of the opening. (Original.)

remain undisturbed for several days. The pressure of the foreign body and the existence of a communication between the cutaneous surface and the deeper parts of the wound naturally increase the chances of sepsis.

Cerebral traumatism and hemiplegia result from the pressure of the retractor in elevating the brain or in the introduction of a large tampon to control bleeding. The latter is in some instances unavoidable; there is no necessity, however, for exerting sufficient pressure with the retractor to damage the cerebral cortex.

Ultimate Effects and Complications; Recurrence.—In a small proportion of cases there has been a return of pain, in some instances on the same side, in other instances on the opposite side. The latter are, however, improperly classified as cases of recurrence, since the symptoms did not return on the side from which the ganglion or its root was removed. Fortunately, as Gowers says,

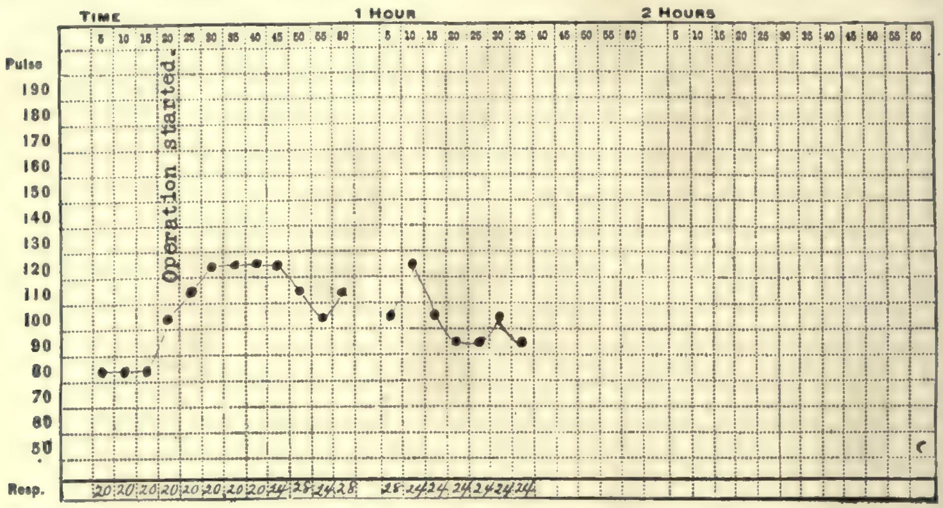

Fig. 143.—Anæsthesia Chart, showing pulse-rate throughout operation (division of sensory root of the trigeminal nerve).

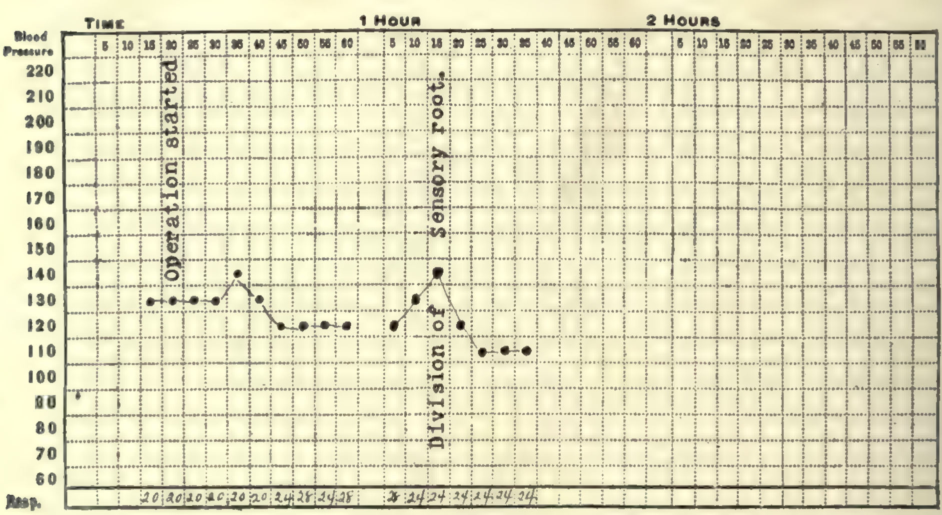

Fig. 144.—Blood-pressure Chart, showing a slight rise of blood pressure during manipulation of the sensory root incidental to its isolation and preparatory to its avulsion.

"neuralgia of the fifth nerve is rarely bilateral." Actual recurrence may be explained in one of two ways:—The lesion may have been central to the ganglion or the operation may have failed to divide all the fibres of the sensory root. Before the technique of the operation had been so carefully elaborated as it is to-day, and when the operator tore out in a fragmentary way as much of the ganglion as he could see or grasp, handicapped usually by a bloody field and improper exposure, the ultimate results were not as good as they are to-day. In a series of two hundred and one cases tabulated in 1903, ninety-three per cent of cases remained free from recurrence.

Cerebral Complications.—In a certain number of cases paralysis has been noted as a complication—*e.g.*, contralateral hemiplegia (Keen, Poppert, and others), homolateral hemiplegia, and monoplegia (Fowler). Disturbance of memory has been recorded, as well as somnolence, aphasia, and delirium. In a series of twenty-seven cases reported by Krause in 1901, temporary somnolence, headache, vertigo and aphasia had been noted as complications. Paralysis and aphasia are attributed to the pressure exerted upon the brain by the retractor and to cerebral embolism. While these complications are by no means frequent, they emphasize the importance of exercising every precaution to protect the brain from undue traumatism.

Fig. 145.—Photograph of Patient (not one of the author's series) with Paralysis of the Upper Branch of the Facial Nerve. Note the absence of wrinkling of the skin of the forehead, the inability to close the eye, etc., following a Hartley-Krause operation upon the Gasserian ganglion. Both limbs of the horseshoe-shaped incision extend a little below the zygoma, and the anterior limb necessarily divided the upper branch of the facial nerve.

Facial Paralysis.—The real significance of facial palsy in relation to the surgery of the Gasserian ganglion is not the disfigurement, which is of course deplorable, but the degree to which it favors the development of keratitis. The inability of the patient to close the eye completely and thus protect the insensitive cornea by keeping it warm and moist, naturally predisposes toward corneal complications. If the paralysis is limited to the upper branch (temporofacialis) (Fig. 145), which is the more important of the two, as it supplies the corrugator supercilii, it is more than likely that this branch was cut by the operator. Kocher's, Cushing's, Lexer's, and Frazier's incisions are so planned as to avoid injuring the nerve. If the paralysis involves the entire distribution—that is, both upper and lower branches—it may be due to the pressure on the cortical centre, although this is unlikely, or to pressure on the nerve trunk exerted by the blade of a retractor in making downward traction on the musculo-cutaneous flap.

In a case of complete facial palsy reported by Porter (*Journal Amer. Med. Assoc.*, May 4th, 1907) it was suggested that paralysis may have been due to the trauma resulting from traction upon the chorda tympani. As a quite unique and still unexplained phenomenon, mention may be made of a case of homolateral hypoglossal palsy occurring in the writer's practice. The paralysis was noted about two days after the operation, and, when the patient was discharged a few days later, it had almost disappeared.

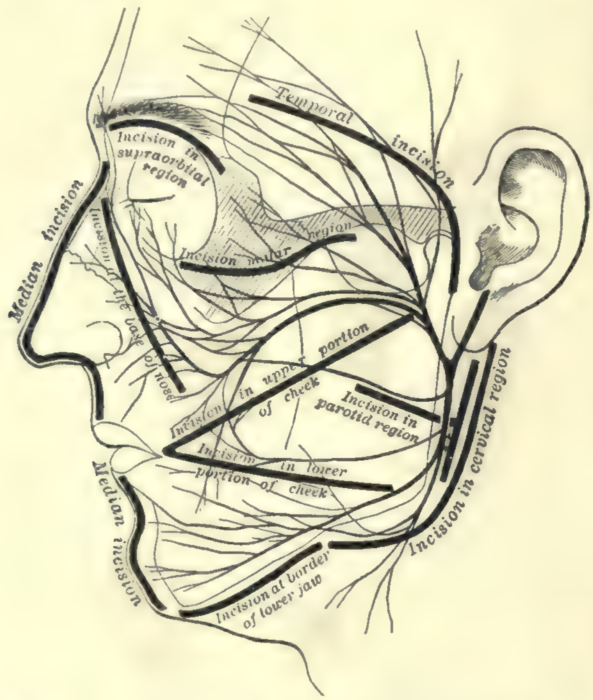

FIG. 146.—Illustration Showing the Incisions which Should be Made in Various Regions of the Face in Order to Avoid Important Branches of the Facial Nerve. (Boeckenheimer.)

VII. **Facial Nerve** (*N. facialis*).—The course and distribution of the facial nerve and its branches have been carefully worked out by Boeckenheimer (*Arch. für klin. Chir.*, Bd. LXXII., Heft 3), with especial reference to the incisions which may be required for the various surgical procedures in this region. In the illustration (Fig. 146) will be seen a number of incisions which may be required, and which have been planned with a view to preserving the integrity of the nerve.

FACIAL PARALYSIS.—Although several experiments had been carried out before,—one as early as 1828,—it was not until 1895 that operations upon the facial nerve were practised on the human subject. Ballance and Stewart, of England, whose labors in the study of nerve regeneration have attracted so much attention, joined the facial nerve to the spinal accessory for the relief of facial palsy. In 1898 Faure, of France, performed the second operation of the series upon a patient who had suffered for eighteen months with a facial paralysis, the result of an injury to the nerve in the temporal bone. The operation was unsuccessful. The third operation recorded in the literature was performed in 1899, by Robert Kennedy, who divided the facial nerve for the relief of facial spasm, and established an anastomosis with the spinal accessory. As a result of the operation function was restored to both groups of muscles, although the movements of the facial muscles were not dissociated from those supplied by the spinal accessory. Since their first experience, in 1895, Ballance and Stewart (*British Medical Journal*, May 2d, 1903) have operated upon six additional cases of chronic facial palsy. The facial nerve was joined to the spinal accessory in all but one instance, in which, for reasons given below, the hypoglossal nerve was selected. The rationale of this procedure was based, to a very large extent, upon the conclusions arrived at in a very creditable work—"Healing of Nerves," published by them in 1902,—in which they advanced the theory that regeneration occurs in the distal end of a divided nerve, even when separated from the central end, but that such regeneration does not reach its full maturity unless the distal segment is joined to the proximal, so as to permit of the transmission of impulses between the nerve centres and the periphery. According to their theory, therefore, attempts to reunite a nerve may be made, regardless of the time that may have elapsed, *provided there still survive muscle fibres susceptible of being innervated by the regenerated and reunited nerve.*

Since the publication of the work of Faure and Furet, in 1898, Manasse (*Arch. f. klin. Chir.*, Bd. LXII., Heft 4) and Breawine (*Travaux de Neurologie Chir.*, 1901, No. 2) have conducted a series of experiments which in every way confirm the results of the earlier investigators.

Paralysis of the facial nerve may be due to a lesion of the nucleus or of the nerve trunk; paralysis of the nerve trunk may follow fractures involving the petrous bone, middle-ear disease, gunshot and stab wounds, and severance of the nerve in operations upon tumors of the parotid or the retro-maxillary space. The most common form of the disease, Bell's palsy, is believed by some (Spiller) to be due to a neuritis within the Fallopian canal, although more recently Clark, from an examination of several specimens removed at operation (*American Journal of the Medical Sciences*, May, 1907), has concluded that it is due to a degeneration of the nerve. Jacobsohn (*Deutsche med. Woch.*, July, 1906, No. 29) has called attention to the increasing number of cases of wounds of the facial nerve, and he attributes the increase to the increasing number of operations on the face and head, particularly the radical operations in the neighborhood of the auditory apparatus.

Indications for Operating on the Facial Nerve.—When the nerve has been completely severed or otherwise irreparably injured, the operation should be undertaken without delay; since the sooner the operation is performed the better is the prognosis. In the more common variety of facial palsy (Bell's facial paralysis) the prognosis is usually good; spontaneous recovery of function occurs in most cases within a few weeks or months. Operative interference in these cases should not be considered until a reasonable time has elapsed. If after from four to six months the facial muscles are still almost completely paralyzed and the reaction of degeneration is pronounced, operation should be recommended. (Spiller.)

Many inquiries have been made as to whether surgical therapy holds out any hope to those patients in whom the palsy has been present for years—five, fifteen, twenty, or more. According to Ballance and Stewart, the keynote to the situation is the condition of the muscles. If the facial muscles are completely atrophied and no longer respond to galvanic stimulation, the prospects of recovery of function are extremely doubtful. Immediately after division of a nerve the peripheral segment begins to undergo regeneration, whether or not it be united to the central segment. As soon as the peripheral and central segments are united the transmission of impulses to the muscles supplies the stimulus necessary for the completion of the regenerative process. The longest period of paralysis to be followed by restoration of function was recorded by Elsberg (*New York and Philadelphia Medical Journal*, August 5th, 1905, page 308). In this case twenty-nine years had elapsed before the operation was undertaken.

Operations upon the Facial Nerve.—If the nerve has been injured at some point peripheral to that at which it makes its exit from the stylo-mastoid foramen, an attempt should be made to effect an end-to-end anastomosis between the divided ends. Even where, as in a case recently operated upon by the author, the nerve had been severed beyond the point where it bifurcates, the free ends of the sectioned nerve should be searched for and united by sutures. This operative procedure is applicable to the traumatic cases, when the nerve has been accidentally severed by gunshot or stab wounds or during operations in the parotid region. When, however, the lesion is in the nucleus or in the nerve trunk on the proximal side of the stylo-mastoid foramen, an anastomosis must be established between the distal segment of the facial nerve and some other motor nerve. For anatomical and functional reasons the choice of nerves lies between the spinal accessory and the hypoglossal. Both are motor nerves and both are sufficiently near the facial nerve to make anastomosis possible. Ballance and Stewart, who have tried both nerves and have had the largest number of cases of spinal accessory anastomosis, have concluded to use in the future the hypoglossal. It is not necessary to review in detail the claims that have been made by some for one, by others for the other nerve. Ballance, Koerte, Taylor and Clark, and Frazier prefer the hypoglossal, while Cushing and others prefer the spinal accessory. Preference should be given to the hypoglossal, first, because the disagreeable complication of associated movements of the shoulder accompanying the spinal accessory anastomosis are avoided; and, secondly, because the cortical centre of the tongue is situated near the facial cortical centre. (See Fig. 145.)

Whether it be true that dissociated movements of the face are matters of education of the newly established cortical centre (either that of the shoulder or that of the tongue), or that the impulses that precipitate these movements originate in the old facial centre or in the tongue centre, the hypoglossal nerve and cortical tongue centre should be chosen. If the first or "educational" theory be the correct one, the hypoglossal nerve is to be preferred because the movements of the tongue are much more closely allied with those of the face than with those of the shoulder, and it is reasonable to infer that the newly selected centre could for this reason be more easily and effectually educated to perform its new function; or, if the second theory should be proven the correct one,—viz., that the impulses must originate in the original facial centre,—the tongue centre has the advantage over the shoulder centre in that the impulses would not have to travel so far from the tongue to the facial centre as from the shoulder to the tongue centre. As to the associated shoulder movements Spiller says:—"The turning of the head or raising the shoulder is only partly controlled by the spinal accessory, and we can readily understand why an overflow into the anastomosed facial nerve occurs if the movement in which the spinal accessory normally has an important part is produced. The cortical centre for the spinal accessory being only a part of the centre for turning the head or raising the shoulder, I doubt very much whether this centre can become so educated that it can assume perfectly the function normally exercised by the centre for the movements of the face. So long as a person laughs or cries, with movement only in one side of his face, the restoration of function is not complete, although it may be very great as compared with the former condition. In employing the hypoglossal as the nerve for anastomosis with the facial it is

FIG. 147.—Diagram Showing the Cortical Origin of the Nerves Supplying Muscles of the Face, Tongue, and Shoulder. (From Ballance and Stewart, in *British Medical Journal*, May 2d, 1903.)

possible that emotional movements may be restored, and such seems to have been the result in a case observed by Koster and Bernhardt (*Berliner klin. Woch.*, 1903, No. 34, p. 788) in which the corner of the mouth on the affected side was moved during laughing."

There is still another point in the technique about which there is some difference of opinion. One must choose between an end-to-end suture or a lateral implantation. Theoretically, at least, the end-to-end suture is to be preferred: first, because the operation is easier of execution; second, because the new cortical centre selected can be more easily educated to preside over facial muscles if its connection is secured from the peripheral muscle originally supplied and from its accustomed centripetal excitation (Rothmann); and, third, because more satisfactory results, as to regeneration, should occur if an entire transverse surface of a healthy nerve is brought in contact with the stump of the facial. (Spiller.) On the other hand, a lateral implantation may seem to be desirable, although more difficult, because it prevents the temporary annoyance that may result from paralysis of the muscles supplied by the hypoglossal, and, according to Taylor and Clark (*Journal of the American Medical Association,* 1906), the results have shown no material advantage in favor of end-to-end suture.

As a modification of the end-to-end (facio-hypoglossal) anastomosis Taylor (*Journal of the American Medical Association,* March 24th, 1906) advocates, whenever possible, the lateral implantation of the stump of the facial into the hypoglossal nerve rather than end-to-end suture, even though the technical difficulties are greater. While theoretically the best results should be obtained by an end-to-end anastomosis, Taylor's experience seems to show that it has no distinct advantages over lateral implantation. When the trunk of the facial nerve seems too short, a longer section may be obtained by uncovering and dividing the nerve in the lower part of the facial canal. If the spinal accessory nerve is preferred, an anastomosis may be effected in one of the following ways: (1) End-to-end between the stump of the facial and spinal accessory; (2) end-to-end between the stump of the facial and the branch of the spinal accessory which innervates the sterno-cleido-mastoid muscle (Faure); (3) lateral implantation of the stump of the facial into the trunk of the spinal accessory.

Facio-hypoglossal Anastomosis.—An incision 8–10 cm. long, and beginning at a point 2 cm. ($\frac{4}{5}$ in.) above the tip of the mastoid process, is made along the anterior border of the sterno-cleido-mastoid muscle. After the cervical fascia has been divided, the posterior margin of the parotid gland is exposed and the gland is drawn forward with a retractor in order to facilitate the exposure of the facial nerve. The latter will be found near the base of the styloid process, about 1 cm. ($\frac{2}{5}$ in.) above and to the median side of the tip of the mastoid process. Here it makes its exit from the stylo-mastoid foramen and passes forward to enter the parotid gland. Two sutures are introduced into the nerve sheath, one on either side, before the nerve itself is divided as close as possible to its exit from the foramen. The hypoglossal nerve is then isolated. It may be identified by remembering its relation to the occipital artery. The nerve passes over the external carotid artery just below the point where the occipital artery is given off. If an end-to-end anastomosis is to be made, the hypoglossal nerve is divided about 2 cm. ($\frac{4}{5}$ in.) beyond the point where it crosses the external carotid artery, in order that the divided end may be reflected and anastomosed to the facial without undue tension. Two sutures are introduced through its sheath before it is divided. The stumps of the two nerves are then brought into apposition, and the site of anastomosis will be found to lie directly over the posterior belly of the digastric muscle. If a lateral implantation is to be done, the hypoglossal should be dissected upward until the stump of the facial can be approximated without tension. This must be done with care in order not to divide the communicating branches which are given off before the pneumogastric upper ganglion of the sympathetic and the two upper cervical nerves. (Taylor.) A slit is made in the hypoglossal nerve, and the wedge-shaped end of the facial nerve is inserted into the slit and retained in place with sutures. The deep fascia is closed with a catgut suture, and the skin incision with a subcutaneous suture.

There are certain features of the technique which are essential to its success: (1) The exposure of the structures should be made by a delicate dissection, with the minimum degree of trauma or mutilation. (2) The wound should be aseptic. (3) The wound should be dry, because the presence of a clot encourages the formation of cicatricial tissue, which, if it should form about the seat of anastomosis, would jeopardize the results. To secure a dry wound, it is advisable to drain the wound for twenty-four hours. (4) The nerves should be handled with great delicacy; they should at no time be grasped with a forceps or sectioned with blunt instruments. (5) The suture should be introduced only through the nerve sheaths and not through the nerve itself, and two, or at the most three, are sufficient. (6) Great care should be taken when the sutures are tied to bring the ends of the divided nerves directly into apposition.

After-treatment.—The after-treatment constitutes a most important feature and one almost essential to a successful result. As a rule, voluntary motion does not return until from the fifth to the eighth month after the operation. Meanwhile electricity and massage must be used faithfully in order to stimulate both nerve and muscle regeneration. Once there are signs of a return of power a course of systematic exercises should be inaugurated. The value of these is twofold: they serve to stimulate nerve regeneration and they assist materially in the education or re-education of the nerve centres, both in the spinal cord and in the cerebral cortex.

Results.—The results which have been obtained from the operation may be graded as follows:—(1) The least that should be anticipated is the ultimate restoration of normal muscular tone—the muscles are no longer flaccid and the face in repose is symmetrical. This degree of improvement may be looked for in from three to five months. (2) If the improvement continues we may confidently expect that there will be a return of voluntary control of certain individual muscles—those, for example, which are concerned in closing the eyelids, in puckering the lips, and in raising the eyebrows. Restoration of voluntary control may return in from five to eight months; it usually begins in the muscles supplied by the lower branch of the facial nerve, as in the muscles at the angle of the mouth, and then extends upward gradually until it involves the muscles of the forehead. (3) The third and last grade, the attainment of which signifies an ideal result, is the return of the finer expressional movements, these movements representing the last stage in the re-education of the cortical centres.

Certain conditions which were in existence before the operation affect the prognosis. The best results should be obtained when an immediate anastomosis has been effected, as after a severance of the nerve in gunshot or stab wounds. The condition of the nerve and the muscles at the time of the operation influences the results. If the paralysis was due to a neuritis, the prospects of recovery are not so good; if the muscles are in an advanced stage of atrophy, the time required for restoration of function will be more protracted. Generally speaking, the shorter the time that has elapsed between the onset of the paralysis and the operation, the better the prognosis.

In a majority of the fifty-seven cases which have been reported (Ito und Soyesima, *Deutsche Zeitschrift f. Chir.*, Bd. XC., 203) the results of the operation have been more than satisfactory. The reports in many instances were published too soon after the operation to enable one to draw any conclusions as to what will be the ultimate result. It is therefore difficult to state with any precision what are the chances of recovery,—whether it will be complete or partial. When the operation has not been an absolute failure, there is, in some cases, restoration of symmetry—sometimes complete, sometimes only partial. In a considerable number there is restoration of control of certain groups of muscles. In most cases it is the muscles of the lower part of the face, and to a less degree those of the upper part of the face, which regain their power. No case has been recorded in which a perfect functional result has been obtained. However, there are no risks peculiar to this operation, and it is now regarded as a recognized surgical procedure, to be resorted to without hesitation in properly selected cases.

VIII. **Auditory Nerve.**—Disturbance of hearing frequently occurs after cranial injuries, particularly after fractures of the middle fossa, and may be due to hemorrhage in the middle ear, to rupture of the tympanic membrane, or to a lesion of the auditory nerve. It is particularly difficult to distinguish between an injury involving the nerve trunk and a lesion of the labyrinth. If the disturbance of hearing is associated with paralysis of the facial nerve, there is greater likelihood of it being due to a lesion of the eighth nerve in the meatus auditorius internus. In a series of ninety cases of basal fracture Graf found six in which there was associated paralysis of the seventh and eighth nerves. The auditory nerve is exposed to pressure from tumors of the cerebello-pontile space or of the anterior aspect of the cerebellar hemisphere. Disturbance of hearing is one of the most valuable localizing signs in determining whether the tumor occupies the one or the other posterior fossa and the relative position of the tumor in the fossa. The seventh and eighth nerves are in absolute contact as they pass from the posterior border of the pons to enter the internal auditory meatus. Both nerves are exposed to view in exploratory operations in this region, and great care must be exercised in order to avoid injuring them.

The only condition which may be said to constitute an indication for operation upon the auditory nerve is tinnitus aurium. Krause, in 1902, was the first to suggest the possibility of relieving persistent tinnitus by intracranial division of the eighth nerve. Since that time the operation has been repeated on several occasions. It is only in selected cases that such an operation could be of any benefit. A central tinnitus would, of course, not be relieved by this operation. The auditory nerve may be distinguished by tracing it to its point of entrance into the internal auditory meatus in the posterior aspect of the petrous bone. Up to the present time the operation has presented no especial difficulties; it differs in no respect from a suboccipital craniectomy for purposes of exploration (suspected tumor). The most difficult feature of the operation is the separation of the auditory from the facial nerve. The latter nerve lies to the inner side of, in fact is almost surrounded by, the auditory. The nerves must be separated with great care in order to prevent facial paralysis. The facial nerve may be distinguished from the auditory nerve partly by the white, glistening appearance of the latter nerve, partly by its much greater size, and partly by the concealed position of the facial nerve.

Krause's patient, a woman sixty-three years of age, was partially relieved immediately after the operation, but she died on the fifth day. In 1903 Wallace operated upon a young woman by the Krause method; the operation was attended with many difficulties and was performed in two sittings. The patient died on the twenty-first day, unrelieved. At the autopsy it was found that the nerve had not been entirely severed, and an examination of the auditory nerve and the cochlea seemed to warrant the belief that the tinnitus was of central origin. In 1904 Parry divided the eighth nerve and accidentally the facial. A year afterward the patient was reported to be considerably better. The improvement had been so gradual that it was questionable whether section of the nerve was in any way responsible for the result. In the fourth reported case the patient died on the third day. The fifth, Bryant's case, survived the operation, but was only partially improved. Thus, of five operations, three died immediately or soon after the operation, and the two survivors were only partially relieved. The writer quite recently performed this operation upon an elderly lady; the immediate results are encouraging, but it is too soon to report the case as cured. As a result of experiments in guinea-pigs and rabbits, Jiromaru proposed an operation in which the cochlear nerve alone is divided. He enters the cochlea at its apex and follows down its axis until he reaches the cochlear nerve. By this method he hopes to avoid injuring the facial nerve. Jiromaru assumes, without sufficient basis for such contention, that the vestibular nerves are normal. He has not tried his method upon the human subject and does not know whether it would or would not relieve the tinnitus. (See also page 731 *et seq.* of this volume.)

IX. **Glosso-pharyngeal Nerve.**—There are no lesions of this nerve of surgical significance. Suffice it to say that certain pathological processes of the posterior fossa may cause functional disturbances which, if recognized, may be of assistance in solving questions of diagnosis. For example, fracture of the base of the skull, inflammatory exudates and tumors in the posterior fossa, may cause a unilateral arrest of function, partial or complete. Under such circumstances there would be anæsthesia of the upper half of the pharynx, disturbance of taste in the posterior half of the tongue, perhaps some dysphagia, and also some loss of reflex excitability in the mucous membrane of the pharynx. Because of their juxtaposition in passing from the inferior cerebellar peduncle to and through the posterior lacerated foramen, the pneumogastric and spinal accessory nerves may be affected by the same processes.

X. **Pneumogastric Nerve.**—Both in its central and in its peripheral relations the pneumogastric nerve presents many features of real interest to the surgeon. As to its central relations it should be remembered that the slow, full pulse of intracranial pressure, especially basal pressure,—as in intracranial hemorrhages and in some cases of contusion of the brain,—must be due to the intimate relations which exist between the nucleus of the pneumogastric nerve and the vasomotor centre in the medulla. In the compensatory rise in blood pressure, that is so frequently seen in cases of this nature, the pneumogastric nerve plays an important part.

The intimate relation between the pneumogastric nerve and the respiratory centre accounts for the fact that, with Cheyne-Stokes respiration, there is usually some alteration in the character of the pulse as well as in the state of the blood pressure. Conditions affecting the circulation of the medulla are often disastrous because of the effect thus produced upon these vital centres. The circulation may be impaired either by local compression or by a general increase of intracranial tension. In the former the causative agent may be a hemorrhage, a serous or purulent exudate, or a tumor in the posterior cranial fossa; in increased tension a tumor of the cerebrum, internal hydrocephalus, meningitis, a cerebral contusion, or a hemorrhage may be the cause. The high mortality following attempts to remove tumors from the cerebello-pontile angle is unquestionably due to the injury inflicted upon the medulla by the necessary manipulations. A moderate degree of compression is usually followed by a temporary compensatory increase in blood pressure. A greater degree of compression is responsible for the final collapse of the circulation and respiration. The pneumogastric nerve in its intracranial course may be damaged by a tumor, an aneurysm, a hemorrhage, a fracture, a periostitis, or a meningitic exudation. There are many conditions which may affect the function of the pneumogastric nerve or its branches in the cervical region. It may be affected, for example, by the compression of an aneurysm, by infiltration of a malignant tumor, or by an accidental or an operative wound. There was at one time considerable apprehension, on the part of the surgeon, as to what might happen if, during the course of an operation, he should injure the nerve. While every attempt should be made to conserve the nerve, the surgeon, at the present time, does not hesitate to sacrifice it, in operations for the removal of a malignant tumor, if the nerve is so involved that the radical removal of the tumor is rendered otherwise impossible. After division of one pneumogastric nerve there may be laryngismus, some difficulty in breathing and swallowing, changes in the voice, diminished inspiratory murmur, asthmatic symptoms, and even pneumonia. (White.) Aspiration pneumonia, which is a cause of death in not a few cases following operations for the removal of a malignant tumor in the buccal cavity, larynx, or pharynx, would be more likely to occur if the nerve were sectioned. As the pneumogastric nerve is an afferent nerve for the vasomotor centre (Gowers), irritation of the nerve may cause a relaxation of the peripheral vessels and a corresponding fall in blood pressure.

In a lobectomy of the thyroid gland, the surgeon is cautioned against the possibility of injuring the recurrent laryngeal nerve, because of its proximity to the posterior aspects of the gland, especially at the point where the inferior thyroid artery is ligated. If the ligature is applied to the artery at its point of entrance into the gland there is little danger of injuring the nerve. The transitory hoarseness that is noticed occasionally is probably due to the traumatism inflicted upon the nerve during the operation. The possibility of including the nerve in a ligature to be applied to the common carotid artery should be remembered. In one instance this was followed by a persistent brassy cough which disappeared as soon as the source of irritation was removed. If the recurrent laryngeal nerve is cut, the vocal cord on the same side remains midway between adduction and abduction and is immovable during respiration and phonation. The hoarseness which follows unilateral paralysis of one recurrent laryngeal nerve is usually only transitory, because the opposite vocal cord can effect contact with the paralyzed cord. Should the hoarseness persist, the peripheral stump may be anastomosed with the trunk of the vagus or the divided end of the spinal accessory. (Kocher.)

The superior laryngeal nerve is the sensory nerve of the larynx. It is of the greatest importance not to injure this nerve in operations upon the mouth and pharynx, since, in rendering the larynx insensible, we favor the development of an inspiration pneumonia. Owing to the possible relation between shock and an injury to the superior laryngeal nerve, as in the performance of a laryngectomy, Crile recommends, as a prophylactic measure, thorough cocainization of the larynx. If the nerve is sectioned, we should, according to Kocher, consider the propriety of effecting an anastomosis with the trunk of the pneumogastric or with some sensory nerve. In one instance of intense neuralgia Kocher stretched the nerve with gratifying results.

Through the gastric branches of the pneumogastric the stomach receives its motor supply. Section of the pneumogastric nerve has been found, in experiments upon lower animals, to lead to the formation of a gastric ulcer. Reflex and central irritation of the vagus probably causes vomiting. In a case in which the vagus was exposed in an operation upon the neck the operator (Boinet) observed that whenever he touched the nerve the patient vomited.

XI. **Spinal Accessory Nerve** (*N. Accessorius*).—The root of the spinal accessory nerve may be injured by fractures of the base of the skull, by tumors, and by inflammatory exudates, as in cases of pachymeningitis. The spinal accessory is a motor nerve supplying the sterno-cleido-mastoid and trapezius muscles. Paralysis of the former muscle would be followed by inability to move the head or chin to the opposite side. When the head is at rest there is no recognizable deviation. Contraction of the muscle on the opposite side will produce a condition similar to that seen in unilateral spasm of the sterno-cleido-mastoid muscle. If the trapezius is completely paralyzed, the shoulder will droop, the scapula will recede from the spine, the power of the deltoid to elevate the arm will be impaired, and the normal contour of the neck will be lost. The spinal accessory is not the only nerve that innervates the muscles in question; the second and third cervical nerves supply the greater part of the trapezius and, to a lesser degree, the sterno-cleido-mastoid muscles. This accounts for the fact that section of the spinal accessory is not followed by complete paralysis of the muscles which it supplies nor by complete cessation of contractions in cases of spasmodic torticollis. As for the trapezius, the only portion exclusively supplied by the sipnal accessory is that which descends from the occiput to the acromial bone. To expose the spinal accessory nerve before the branch for the sterno-cleido-mastoid muscle is given off, an incision may be made from the tip of the mastoid process to the angle of the jaw; to expose the branch that goes to the sterno-cleido-mastoid muscle the incision should be made parallel to the anterior border of the muscle, from the tip of the mastoid process to a point a little below the junction of the middle and upper thirds of the muscle, where the main trunk passes behind it to emerge from the posterior border; and, finally, to expose the nerves after the branch to the sterno-cleido-mastoid has been given off, the incision should be made along the posterior border of the middle third of the muscle.

While the surgeon often exposes the spinal accessory nerve during the course of an operation in the anterior or the posterior triangle, there are two occasions which necessitate the deliberate isolation of the nerve—one, namely, in the treatment of facial palsy, and the other in the treatment of spasmodic torticollis. In the latter condition, if the sterno-cleido-mastoid is alone involved, it may be necessary only to stretch or avulse the spinal accessory. When, as is so often the case, the trapezius alone, or the complexus, the splenius capitis, the recti, and the oblique muscles are implicated, the posterior divisions of the first, second, and third cervical nerves must be resected.

XII. **Hypoglossal Nerve.**—Within the skull this nerve is exposed to the same lesions which affect the ninth, tenth, and eleventh nerves. Paralysis may result from the pressure of a tumor, an exudate, a hemorrhage, or an aneurysm of the vertebral artery. Outside the skull the nerve is exposed to danger during operation in the anterior cervical triangle, and it may also be injured by the presence of a tumor. When the nerve is paralyzed the tongue will be protruded toward the affected side, the raphe is curved with its convexity toward the unaffected side, and on the sound side the tongue will be atrophied, shrunken, wrinkled, and flaccid. Articulation, mastication, and swallowing will also be impaired, but only to a slight degree. The hypoglossal nerve is one of two which may be selected for anastomosis with the stump of the facial nerve in the treatment of facial paralysis. (See page 410.)

To expose the nerve an incision is made from the tip of the mastoid process to the bifurcation of the common carotid artery, along the anterior border of the sterno-cleido-mastoid muscle. After the skin, platysma, and deep fascia have been divided the nerve may be identified by its relation to the occipital artery. After descending in a vertical direction, parallel with the spinal accessory in the upper third of the neck, the nerve curves toward the median line, crosses the external carotid artery where the occipital artery is given off, passes under the digastric and stylohyoid muscles, and finally reaches the anterior border of the hypoglossus.

SURGICAL DISEASES, CERTAIN ABNORMITIES, AND WOUNDS OF THE FACE.

By CHARLES G. B. de NANCRÈDE, M.D., Ann Arbor, Michigan.

GENERAL CONSIDERATIONS.

A PRELIMINARY survey of the blood and lymph circulation of the face is requisite for a correct understanding of the pathology of its injuries and diseases. The sources of the blood supply are so numerous and anastomoses are so free, that, to arrest hemorrhage from the soft parts, it is usually requisite to secure both the proximal and the distal extremities of even the smaller vessels. Bleeding of importance, whether primary or secondary, must therefore, when possible, always be arrested in the wound itself, because the only other resort, in severe and persistent bleeding from the soft parts of the face or from its bony structures, consists in tying both external carotids. Theoretically, after such a procedure collateral circulation through other vessels may give rise to trouble, but in practice this is rarely the case. The vascularity of the facial tissues explains the repair of contused and lacerated wounds with little if any sloughing, the processes often closely simulating primary union. The most extensive wounds usually heal with comparatively slight deformity and scarring. The lesson is obvious, viz., always carefully coaptate every facial wound, and trim lacerated tissues only when the conditions to be mentioned later prevail. Of equal pathological import is the anatomical fact that, owing to the absence of valves in the facial veins, infection may travel by the blood current into or through the cerebral vessels, and that an infective thrombo-phlebitis, starting in the upper lip or contiguous parts, often leads either to fatal thrombosis of the cerebral sinuses or to pyæmia.

The following résumé of the anatomy of the facial lymphatic distribution, after Poirier and Cunéo, should be studied because it demonstrates the route pursued by the infective agents and the primary sources of lymph-node infection, pyogenic, tuberculous, or malignant.

Not only the groups of lymph nodes of the head and face should be studied, but also the lymphatic apparatus of the different organs whose vessels are tributaries of these nodes.

The lymph nodes of the neck (Figs. 148 and 149) form a "true glandular collar, placed at the junction of the head and neck." On either side a more or less vertical main chain passes downward to the base of the neck, accompanying the great vessels beneath the sterno-mastoid muscle, and in relation with several of the most important nerves. To either side, and more superficially located, are several less important secondary chains of lymph nodes.

The cervical collar is divisible, for convenience of study only, into (1) the suboccipital group and the aberrant nodes of the nape of the neck connected with it; (2) the mastoid group; (3) the parotid and subparotid groups; (4)

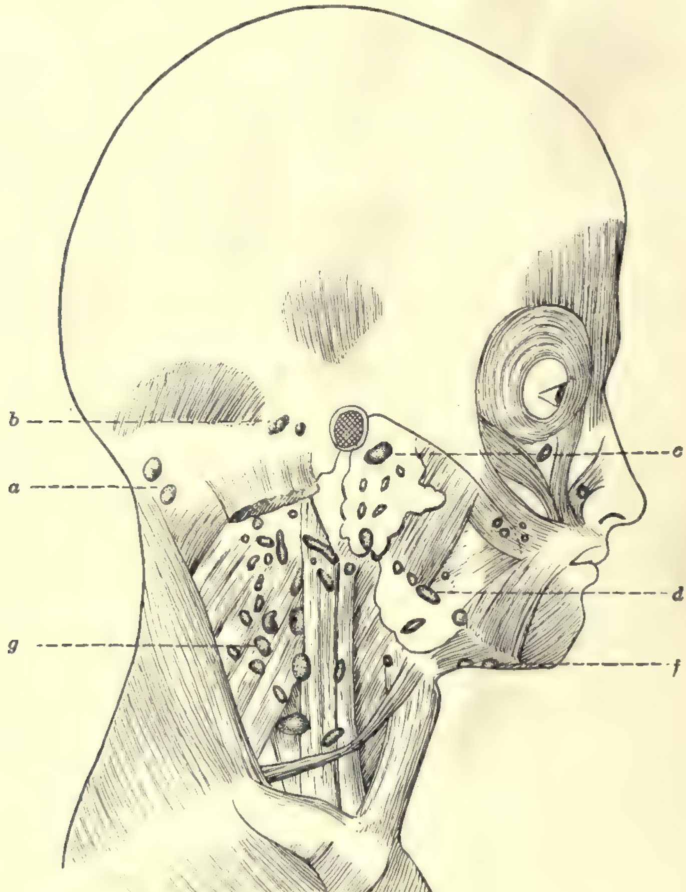

Fig. 148.—General Arrangement of the Groups of Lymph Nodes Belonging to the Head and neck. (After Poirier and Cunéo: "Anatomy of the Lymphatics.") *a*, Occipital nodes; *b*, mastoid nodes; *c*, parotid nodes; *d*, submaxillary nodes; *f*, submental nodes; *g*, deep cervical chain. In the picture the facial nodes are represented by four small bodies that lie a short distance to the left of the angle of the mouth.

the submaxillary group, of which the facial nodes form an off-shoot; (5) the submental nodes; and (6) the retropharyngeal nodes, more or less directly connected with the preceding groups.

While it is recognized that all these groups of nodes may be involved in facial troubles, especially when the normal routes for lymph are blocked, so that retrograde metastasis occurs, yet for present purposes only those which are likely to be primarily involved in facial diseases will be dwelt upon, although the others will receive cursory mention.

Distribution of the Different Groups of Lymph Nodes.

Suboccipital Group.—There are from one to three suboccipital nodes which are located most commonly near the attachment of the complexus muscle, externally to the outer border of the trapezius; they are subaponeurotic and intimately related to the terminals of the occipitalis major nerve. Lymph passes through these nodes from the occipital portion of the hairy scalp, emptying into the uppermost nodes of the substerno-mastoid group.

Mastoid Group.—Lying upon the insertion of the sterno-mastoid muscle, immediately below the retrahens auris, and connected by two or more lymph vessels, is the mastoid group, usually consisting of two nodes. The lymph passing through these nodes comes from the hairy scalp of the temporal region, from the posterior surface of the external auditory meatus, and from the internal surface of the auricle, except the lobule; the efferent lymph empties into the upper substerno-mastoid nodes after traversing the superior insertions of this muscle.

Parotid Group (Figs. 148 and 149).—There may be both a subcutaneous and a subparotid collection of nodes, although the former are inconstant. The nodes in the parotid space are either situated just beneath the parotid fascia, between it and the gland substance, or they actually lie in the latter. These deep nodes are irregularly located throughout the gland substance, but they are usually grouped along the external jugular and external carotid vessels, while one node is constantly placed close to the angle of the jaw, in contact with the deep cervical fascia. The two or three nodes (often reduced to a single node) that lie beneath the parotid fascia, are usually located immediately in front of the tragus and are termed the pre-auricular nodes (or node). The

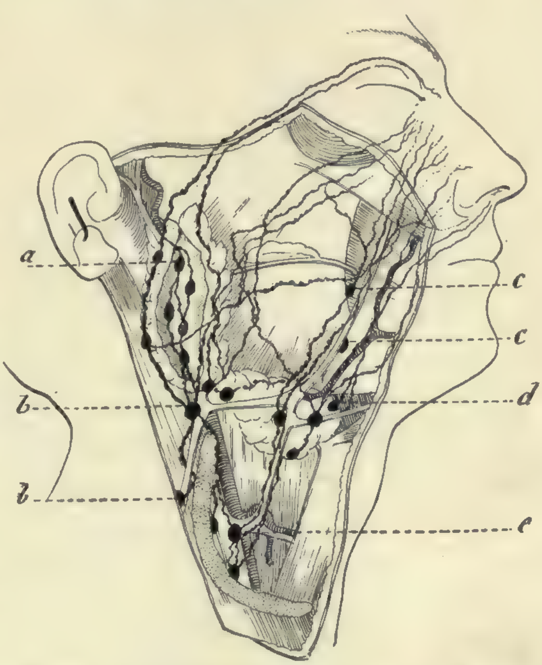

Fig. 149.—Lymphatics of the Neck. (After Kuettner, in Poirier and Cunéo's "Anatomy of the Lymphatics.") *a*, Parotid lymph nodes; *b*, *b*, nodes of the external jugular chain; *c*, *c*, facial nodes; *d*, submaxillary nodes; *e*, nodes of the internal jugular chain.

lymph from the external surface of the auricle, from the external auditory canal, from the tympanum, from the skin of the temporal and frontal regions, from the eyelids, and from the root of the nose, passes through the group of parotid nodes. Possibly lymph vessels that drain the mucous membrane of the nasal fossæ, as well as some that come from the back portion of the superior dental alveoli, also empty their lymph into these nodes. The efferent vessels terminate in the nodes around the external jugular vein, where this emerges from the parotid gland, and in the substerno-mastoid nodes. While their number is ordinarily estimated at from ten to sixteen, the parotid nodes are really more numerous, since microscopic sections reveal numerous minute nodules of lymphoid tissue, while potential nodes, in the form of masses of lymphoid tissue surrounding the glandular (parotid) acini, are everywhere present.

Subparotid Group.—These nodes are placed between the parotid gland and the pharynx, in contact with the great vessels. Lymph from the naso-pharynx, the nasal fossæ, and the Eustachian tube passes through these nodes, and by way of their efferents reaches the deep cervical chain.

Submaxillary Group (Figs. 148–152).—From three to six in number, these nodes lie along the inferior border of the maxilla, from the insertion of the anterior belly of the digastric muscle to the angle of the jaw, resting upon the submaxillary gland. Lymph reaches these nodes from the nose, the cheek, the upper lip, the outer parts of the lower lip, almost the whole of the gums, and the anterior third of the lateral border of the tongue. Their efferent vessels empty into the deep cervical chain, more especially into the nodes lying over the bifurcation of the common carotid artery. Since this article deals only with facial diseases and injuries, the lymphatics of the mouth proper, the ear, the naso-pharynx, and the lower portion of the neck will not be described. The various groups which directly or indirectly may become infected from facial conditions have been adequately described, and it now remains only to speak of the facial lymphatic trunks through which infection may reach the cervical groups already mentioned.

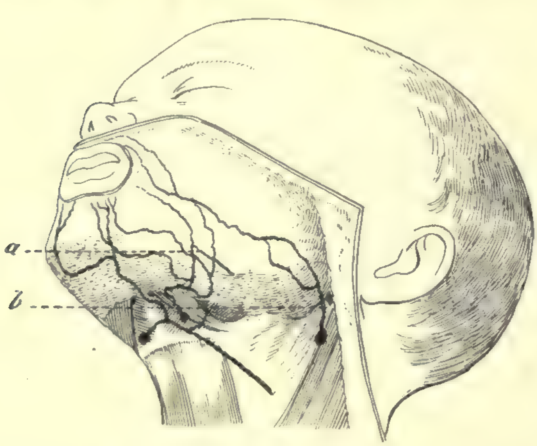

FIG. 150.—Lymphatics of the Lips. (After Dorendorf, in Poirier and Cunéo's "Anatomy of the Lymphatics.") *a*, Trunk ending in the submaxillary nodes; *b*, collecting trunk of the upper lip terminating in a node of the external jugular chain.

Facial Lymphatics (Figs. 149, 150, and 152).—The frontal lymphatic trunks, ten or twelve in number, drain the supraorbital region and root of the nose, and empty into the parotid group of nodes. The temporal lymphatics form two groups, the anterior terminating in the parotid, the posterior in the mastoid nodes. The lymphatics of the eyelids and conjunctiva form a fine-meshed network from which arise two terminal groups of lymph vessels. Some course inward to empty into a median or para-median trunk, which springs from the intersuperciliary space and ends in the submaxillary group of nodes. Others, draining the outer three-fourths of the eyelids, run downward and backward to empty into the parotid group of nodes.

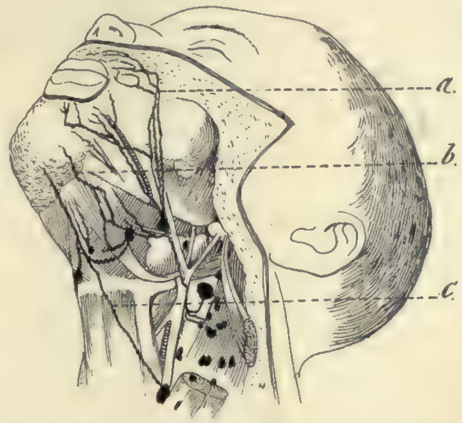

FIG. 152.—Lymphatics of the Lips. (After Dorendorf, in Poirier and Cunéo's "Anatomy of the Lymphatics.") *a*, Collectors of the upper lip ending in the submaxillary nodes; *b*, collectors of the lower lip ending in the same nodes; *c*, lymph vessel passing directly to a node of the internal jugular chain.

Lymphatics of the Nose (Fig. 149).—These originate by a network which at the root of the nose is coarse but becomes finer over the alæ and lobule. The radicles communicate across the median line with the network of the opposite side and with the lymphatics of the nasal vestibule, and these in turn with the vessels of the Schneiderian membrane. The lymph trunks form three groups. The first of these passes from near the root of the nose along the upper margin of the orbit, to terminate in the upper parotid nodes. The middle vessels, which compose the second group and are usually three in number, arise from the root and sides of the nose, run along the lower border of the orbit, and pass downward through the lower portion of the parotid gland to end in the lower parotid nodes. The third group is the most important. It comprises from six to ten trunks which spring from the entire extent of the cutaneous network. They run with the facial blood-vessels and terminate in the submaxillary nodes. Some of them may be interrupted in one of the facial lymph nodes.

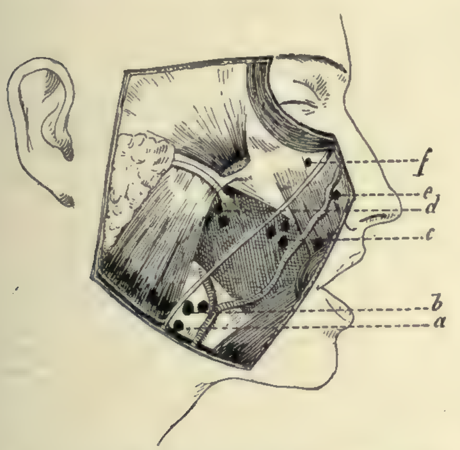

FIG. 151.—Facial Lymph Nodes. (After Buchbinder, in Poirier and Cunéo's "Anatomy of the Lymphatics.") *a*, Inframaxillary node; *b*, submaxillary node; *c*, buccinator node (middle mass); *d*, buccinator node (posterior mass); *e*, node of the naso-genial groove; *f*, infraorbital node.

Lymphatics of the Lips.—There are two networks that communicate at the free border of the lips, one cutaneous and the other mucous. On either side a couple of submucous and two or three subcutaneous trunks carry the lymph from the upper lip directly to the submaxillary nodes. (Fig. 152.) Sometimes one trunk communicates with a collecting trunk from the lower lip, or possibly it may empty into one of the nodes related to the external jugular, where it emerges from the parotid gland. From two to four main trunks on either side drain the lower lip; those from the mid-labium reach the submental nodes, while those arising near the angles of the mouth terminate in the anterior submaxillary nodes. The two or three submucous vessels on each side run downward and outward, terminating in the submaxillary nodes. To quote the final conclusions of the authors from whose treatises these data have been secured, "To sum up, the submaxillary and submental glands [nodes] represent the first glandular relay of the lymphatics of the lips; it is only exceptionally that we see one of these vessels pass by this first station and directly reach the deep cervical glands." The importance of this statement from a clinical point of view cannot be overestimated.

The superior labial trunks neither cross nor anastomose, and this is also true of the submucous vessels of the lower lip. In contradistinction to this the subcutaneous trunks of the lower lip may reach past the median line or anastomose, thus accounting for the not uncommon involvement of the opposite submental and submaxillary nodes in asymmetrical carcinoma of the lower lip. This emphasizes the propriety of clearing out both sides of the neck in the submental and submaxillary regions, when dealing with carcinoma of the lower lip.

The lymphatics of the auricle and external auditory meatus will be described elsewhere in connection with diseases of these parts.

A thorough acquaintance with the facts here given in outline will usually enable the practitioner to decide, with much confidence, in many cases of infection, what is the primary source and what nodes should be removed when operating for malignant disease.

Of equal importance with a knowledge as to the areas drained by the lymph trunks is the location of the facial nodes the enlargement or the tenderness of which is often the first signal of some more distant infection. There are usually three groups lying in the course of the facial vessels. (Fig. 151.) The superior group is formed of a suborbital node, a malar node, and one in the naso-labial groove. The middle or buccinator group is present only in about one-third of the subjects examined and rests upon the outer surface of the buccinator muscle. One or two nodes of this group lie behind the facial artery, close to the parotid duct where it passes through the muscle, while one or two are interposed between the artery and vein and are overlaid by the posterior fibres of the zygomaticus major muscle. Another node, the commissural node, is sometimes found in front of the vessels, where it lies upon the orbicularis oris muscle "8 to 10 mm. from the labial commissure." The most inferior group of nodes is located upon the external surface of the lower jaw between the border of the depressor anguli oris and the anterior margin of the masseter muscle. They are covered by the platysma muscle, and are intimately connected with the facial blood-vessels. Sometimes a node situated upon the lower border of the inferior maxilla, the inframaxillary node, renders this supramaxillary node continuous with the submaxillary group of nodes.

INJURIES OF THE FACE.

Contusions.—Contusions, and contused wounds caused especially by the application of blunt force, produce somewhat different results according to the intimate or loose connection of the skin with the subjacent parts. Thus, contusion of the eyelids or their neighborhood results in widespread infiltration of blood and serum from a trivial injury, *i.e.*, a "black eye," because of the abundance of loose connective tissue in the eyelids and orbital cavity, while a more severe injury of the chin leads to a comparatively circumscribed effusion of blood into the skin and subjacent tissues. Abrasions of the surface often coincide with contusions, and they are at times the infection atria for a severe cellulitis. Blunt force applied over sharp edges of bone, such as the orbital margins or the bridge of the nose, where the skin is tightly stretched, often produces a contused wound simulating an incised one, owing to division of the soft parts by the bone from within. The incisor teeth, in falls on the face, quite often completely penetrate the free borders or even the substance of the lip. Contusion with abrasion, when the blades of the obstetrical forceps are not properly applied, is not uncommon during instrumental delivery.

Treatment.—Contusions should be carefully disinfected and aseptically dressed lest the bacteria that infest these parts invade the partially devitalized skin, giving rise to abscesses and even pyæmia from infective thrombo-phlebitis. The larger subcutaneous accumulations of blood nearly always disappear in the course of time, rarely requiring aspiration or incision. In contused wounds, after the parts have been shaved and scrupulously disinfected and the bleeding arrested, the edges should be coaptated by sutures at sufficient intervals to permit the escape of blood and pus, should the latter form, and then supporting strips of gauze and collodion should be applied. Suturing should always be done where the nostrils, eyelids, and mouth are concerned.

The advice to smooth off ragged edges and tags of tissue is questionable except in experienced hands, because the free blood supply often enables greatly damaged tissues to recover. Nevertheless, the judicious employment of such measures in well-selected cases often gives a better cosmetic result than pure conservatism.

Extensive contused wounds, where the vitality of loosened flaps is questionable, had better be lightly packed with iodoform gauze for a few days, when, if the soft parts are then clearly viable, secondary suturing can be employed, due provision being made for drainage. If sloughing takes place, abundant time must elapse after cicatrization to insure that the maximum of deformity has been attained before resorting to any plastic operation.

Lacerated Wounds.—Lacerated wounds result from the bite of a dog, or the kick of a horse, from the finger of the accoucheur tearing open the mouth or eyelids during delivery of the head, from children catching button hooks or other objects in the nostril, mouth, or eyelids, from falling upon meat hooks or being caught by hoisting hooks of derricks, etc.

Treatment.—Disinfection, arrest of hemorrhage, and coaptation of the edges as suggested for incised wounds, are all indicated, because even irregularly torn facial wounds unite in part or completely, as do incised wounds.

Incised Wounds.—Owing to the extreme vascularity of the facial tissues healing takes place rapidly and pyogenic infection does not commonly occur nor is it often virulent. Such secondary results as phlegmons are therefore uncommon. As a rule, hemorrhage is free even when no distinct bleeding points are recognizable.

Treatment.—Under suitable aseptic precautions any dirt or foreign body that may be present should be removed. When it is ascertained that the main trunk or some of the larger branches of the facial nerve have been severed the divided ends should be approximated by fine sutures, and a similar practice is necessary in the case of a wounded salivary duct. In a penetrating wound of the cheek, however, the proximal end of the duct should be stitched to the mucous membrane. Paralysis often proves not to be permanent. All bleeding which is not arrested by placing the wound surfaces in contact, by the pressure of sutures, or by firm bandaging, should be adequately dealt with, for partial wounds of the facial artery or its branches not uncommonly lead to arterial hæmatomata (traumatic aneurisms), with repeated and dangerously free hemorrhages.

The mobility possible in any portion of the face and necessarily present in many regions, and the close connection which exists between the skin, the rather dense subcutaneous tissue, and the muscle fibres which pursue various courses, render it necessary, in all but the more insignificant wounds, to employ sutures if it be desired to secure a minimum of scarring.

When the muscular fibres are cut across, suture alone can secure a narrow linear scar. But if the wound is limited in extent, if it penetrates only down to the fascia, if it runs in a direction parallel to the underlying muscular fibres, and if its edges do not tend to be drawn apart by the necessary movements of the eyelids, mouth, or jaws, it may be found practicable to secure accurate and firm coaptation of the edges by the application, transversely, of strips of gauze to which collodion is applied. (See article on "Minor Surgery" in Vol. IV.) By the adoption of this course all suture scars are avoided. If the skin is thick enough it is possible to bring the edges of the wound closely together by means of subcutaneous stitches of catgut passed with a fine needle. When horsehair is available, which can be threaded on an ordinary round sewing-needle, through-and-through suturing is the safer course to adopt. It leaves practically no discernible stitch scars, because this suture material absorbs no septic material and consequently infection of the stitch tracts does not occur and there is no resulting ulceration. Horsehair, however, is apt to break when it is tied tightly, and therefore in some cases it may be found preferable to employ fine silk with small round needles. In many instances a very few stitches will suffice if the wound margins are drawn together with gauze and collodion. Except when the pressure of compresses and bandages is requisite to arrest oozing, incised wounds need only the lightest dressing to prevent accidental infection. Secondary neuralgias from involvement of the nerve filaments in a cicatrix, or from the development of a neuroma, call for excision.

A partially or completely severed tip of the nose, auricle, lip, cheek, or chin can often be saved by carefully suturing it in position, even if considerable time has elapsed since the occurrence of the accident. Certain precautions, however, are requisite for success. It is necessary, for example, to place the severed part in warm normal salt solution as soon as possible; all hemorrhage from the wound should be completely arrested; perfect asepsis should be secured; and, finally, the suturing of the separated part to the living tissues must be done with all possible accuracy.

Secondary hemorrhage or the formation of arterial hæmatomata (aneurisms) is due to faulty technique in arresting the bleeding, and must be treated on general principles (opening the wound and securing both ends of any wounded artery as well as all other bleeding points). Infection likewise must be remedied by cutting the sutures that are too tight and that consequently interfere with drainage, and afterward packing the wound lightly with gauze; or, instead, tube drainage may be instituted, or the wound may be simply allowed to gape, a moist antiseptic dressing being applied to the parts.

Wounds of the lachrymal sac commonly heal without intervention, although stenosis is apt to take place.

In the rare event of division of the levator palpebræ muscle, in wounds of the upper eyelid, the proximal end must be sought and sutured to the lid.

Punctured Wounds.—Punctured wounds are chiefly of importance because of complications, such as wounding of deep-seated vessels, opening of the nasal cavities or of the cranial cavity, as by penetration of the roof of the orbit or of the cribriform plate of the ethmoid, and the possible presence of a foreign body within the cranium or in the temporal fossa—as where a portion of the vulnerating body (ferrule of a cane or umbrella) becomes separated from it and remains behind.

Treatment.—When serious hemorrhage is present, the better practice is to tie both external carotids rather than attempt the slow and difficult operation required for securing the internal maxillary at the point injured. In the case of a foreign body, the lodgment of which in the deeper parts is sometimes revealed by the fact that an examination of the vulnerating object shows a part of it to be missing, it is imperative to search for and if possible remove it. In such a search the aid of the *x*-ray may be invoked. Empyemas of the secondary nasal cavities, deep-seated abscesses, and intracranial abscesses all call for secondary drainage and removal of any foreign body that may be present. As in the case of a bullet wound no examination by probe or finger should be made unless the presence of a foreign body is reasonably certain. The likelihood of establishing deep-seated infection by such an examination emphasizes the importance of this rule. The better practice is to employ the *x*-ray when available.

Gunshot Wounds.—It is the common practice to include under gunshot wounds not only such as result from bullets and small shot, but also those produced by solid shot, fragments of shell, or pieces of rock or gravel set in motion by bullets, shell, or solid shot. Only the first two classes will be here considered, because the remaining ones are either contused or lacerated wounds, or a combination of both, with or without the lodgment of foreign bodies, and should be treated on the general principles applicable to similar traumatisms produced in other ways.

In civil practice the cases of attempted suicide, where the muzzle of a shotgun is placed in the mouth or near the head, form a class of injuries almost by themselves. In such cases the most extensive shattering of the bony framework of the face is combined with the most dreadful laceration and distinct burning of the lips and cheeks, which are split and torn in various directions. At times a wide gap results from the actual carrying away of bone and soft parts. As this article is solely concerned with traumatisms and surgical diseases of the face (not including the mouth), nothing more need be said than that penetrations of the base of the skull are quite common in this class of cases, and that primary and secondary hemorrhages are the most dangerous complications. Such hemorrhages, when free, often prove fatal directly from the amount of blood lost; and when they are less profuse they so lower resistance that the patient readily succumbs to infection.

Treatment.—If death from hemorrhage does not occur, much can be done for the worst injuries. Thorough arrest of all hemorrhage is imperative. Ligatures should be applied to all bleeding points, and when the hemorrhage comes from the facial, the lingual, or the temporal artery, it is necessary to tie both ends of the divided vessel, the track of the wound being enlarged for this purpose whenever it is found necessary to gain more space. If any oozing remains it must be controlled by iodoform-gauze packing and by the application of a bandage. Severe, deep-seated hemorrhage, if it come from the internal maxillary or the deep temporal artery, is better dealt with by ligature of one or both external carotids. If this measure, supplemented by packing, does not succeed, direct attack at the seat of injury should be instituted.

If the lingual, facial, or thyroid artery is injured, one must be careful not to overlook the primary danger that a large quantity of blood may enter the trachea. Then, again, the falling back of the base of the tongue, when its attachments to the lower jaw are severed, may induce asphyxia. At a later stage, in cases where the tongue is injured, the pouring out of inflammatory exudates into the tissues of the wounded organ may induce a fatal œdema of the glottis.

When an eye is hopelessly damaged, it is better to remove the entire organ in order to avoid the possibility of future sympathetic ophthalmia.

When much shattering of bone has occurred it is often practicable by judicious suturing to hold all attached fragments of bone approximately in place, especially the fragments of the upper jaw, the tough muco-periosteal tissue of the alveolar borders and that covering the hard palate giving a firm hold for the sutures. As a rule with very few exceptions, only absolutely detached fragments of bone should be sacrificed. For securing the larger fragments, especially those of the lower jaw, additional sutures of wire or catgut should be used, or some form of dental clasps may serve a good purpose if a skilful dentist can be secured to adjust them. Some necrosis is to be expected, but it is often astonishing how small is the amount of bone that dies and how slight the consequent deformity. Later, after the parts have entirely healed, dental prosthetic apparatus may accomplish much. (See article on "Prosthesis in Relation to Oral Surgery" in the next volume, Vol. VI.)

FIG. 153.—Cicatrix after a Gunshot Wound of the Chin. From a wax cast. ("Medical and Surgical History of the War of the Rebellion.")

The same remarks are applicable to the injuries involving the soft parts. Save and suture together all mucous membrane, in order to avoid cicatricial ankylosis of the jaws. Do not attempt to do any trimming, except perhaps to remove loosely hanging shreds of tissue, and to coaptate by deep sutures all such portions as can be brought into fairly close contact, leaving to Nature to do what she can, and to a secondary operation, if requisite, to remedy the remaining deformity. Disinfection of the mouth and the administration of the requisite liquid nourishment are imperatively needed. Secondary infections often give rise to trouble, but, owing to the vascularity of the parts, it is really surprising how slight this may prove. It is sometimes difficult to arrest the secondary bleeding, and for the accomplishment of this object it will generally be found necessary to employ some one or all of the measures advised for the staunching of primary hemorrhage. Secondary bleeding from infected wounds should be controlled by measures addressed to the wound in non-infected tissue.

In the treatment of ordinary bullet wounds of the face do nothing without a clear indication. In minor wounds shave the adjacent skin and disinfect both it and the mucous surface, if the latter is involved; apply to the parts an aseptic dressing. Arterial hemorrhage must be arrested by forci-pressure or by the application of a ligature if more than a minute twig is concerned. The bullet, unless readily accessible, should not be sought for. Iodoform packing of the accessory sinuses of the nose, when they are involved, is often advisable. In rare cases it is permissible, for cosmetic reasons, to trim slightly an irregular wound. If ligation in continuity of one of the larger vessels has to be done, it is important, in order to lessen the risk of secondary hemorrhage, carefully to protect the wound against infection.

Burns and Scalds (Fig. 154).—The dangers of burns and scalds in the facial region are both immediate and remote. Thus, a most superficial burn or scald, otherwise trivial, may damage or destroy vision, or, by the direct action of inhaled steam or heated gases, dangerous obstruction to respiration may arise from swelling of the tissues of the glottis. The remote dangers are usually due to cicatricial contraction and rarely threaten life, although serious ectropion may imperil vision. Besides the dreadful deformities resulting from burns—as where the mouth is so drawn upon as to be kept permanently open, or almost obliterated, where the nasal openings are narrowed or occluded, etc.—there is of course some risk from sepsis, from tetanus, and from other infections. In the so-called chemical burns, which are often strictly limited to the face and are the result of the action of strong acids or alkalies, the eyes are frequently injured or destroyed. The soft parts are sometimes so deeply penetrated as eventually, after separation of the slough has occurred, to lay bare the facial bones; in which case necrosis not infrequently occurs later.

The differentiation between burns and scalds is usually easy. In the former the cutaneous hairs are destroyed or remain as brittle, curled, manifestly burned stumps. In the case of scalds, the hairs remain on the damaged area, unless the cuticle has been removed by the scalding; but even then the presence of undamaged hairs on the immediately adjoining healthy skin will show that the causative agent has not been fire.

Treatment.—For a purely superficial burn or scald, where the injury is limited to reddening with some vesication, allowing the injured part to heal by scabbing is probably the quickest but not always the most painless method. If nothing has been applied to the surface it is sterile and can be kept so, provided a number of layers of aseptic gauze are disposed over a framework in such a manner that the material shall not touch any portion of the face, while at the same time it filters the air free of germs. Aseptic puncture of all blebs, to permit escape of

FIG. 154.—Results of Burns of Face, Arms, and Hands. The maximum of distortion had not been reached at the time when the picture was taken. (University Hospital, Ann Arbor, Michigan.)

the serum, should be repeated when necessary, care being taken not to remove the epithelium, which will, with the desiccated serum, form aseptic scabs beneath which reproduction of the epithelium will take place in the course of from ten to fourteen days. If greasy applications have been made, the air treatment is often inapplicable; indeed, where partial or complete destruction of the skin has occurred at any point, if a dry dressing seems advisable, many layers of aseptic gauze should be employed. The more superficial layers of gauze should be frequently removed when soiled, as in the vicinity of the mouth, but those portions of the dressings which are directly in contact with the burned areas should never be unnecessarily disturbed, because damage to the healing surface is inevitable under these circumstances. If it seems possible to secure healing with such a small amount of discharge that it will not accumulate beneath the scabs, finely powdered bismuth subnitrate may also be dusted over the lesion. Sterile zinc or bismuth ointments are probably the best dressings for the average case, as they can be easily and painlessly removed and they aseptically poultice the parts,—*i.e.,* hey keep them warm and moist—the essentials of a poultice,—thus favoring rapid separation of the sloughs. This is a most desirable result, since the presence of sloughs maintains a widespread and deeply seated hyperæmia, stimulating the permanent tissue cells to division and supplying them with abundance of pabulum for further development into the adult cells that form the dense, powerfully contracting connective-tissue scars which follow sloughing burns. It cannot be denied that the exercise of every precaution will not entirely prevent accumulations of zinc or bismuth on the recently healed or partially cicatrized areas. Nevertheless, these often serve as artificial scabs beneath which epidermization progresses. By the non-employment of gauze, and the spreading ointment rather thickly on either sterilized sheet lint or canton flannel, the withdrawal of the fatty vehicle will be retarded. Hence these almost dry accumulations of the drugs often take longer to form than the period of time elapsing between two dressings. By careful and liberal use of alcohol, the practitioner can restrain within due limits the accumulation of ointment or remove it if it should accumulate.

Should the injury have been caused by a caustic alkali or acid, neutralization of this with sterile solutions of the appropriate alkalies or acids is indicated. If this has already been done at the time when the patient was first seen, attempts at disinfection (?) may be tried with solutions of non-irritant germicides, proper aseptic dressings being applied afterward. In our endeavor to lessen cicatricial deformity we should keep certain general principles, second only to asepsis in importance, constantly in view during the treatment of facial burns. For example, ulcerated fissures—which certainly prolong the healing, add to the scarring, and afford avenues for local infection, that manifests itself in the form of abscesses, etc., or even in that of a constitutional infection—can often be avoided by the adoption of such measures as will keep the eyelids and the mouth in a quiet state.

Nobody has yet discovered, nor is anybody likely in the future to discover, a mechanical method of dressing facial burns that will prevent the deformity arising from scar contraction. Attempts made to prevent such deformities in other portions of the body have usually failed, or have added to the scar tissue by prolonging the healing. Hence, in burns of the face, the aim should be to secure the most rapid cicatrization attainable, the problem of remedying the deformities being left for solution at a later date.

The earliest possible separation of sloughs should be encouraged, for the reasons already given. Finally, skin grafting, preferably by the Thiersch method, should be done as soon as the granulations are reasonably healthy, although Wolfe grafts* may occasionally serve the required purpose better. Despite all efforts, deep burns will usually require plastic operations—as, *e.g.*, in ectropion, in stenosed or closed nostrils, in deformed mouth, etc. In burns resulting from the explosion of black gunpowder, after all the partially embedded grains have been removed by a cataract needle or spud, those superficially located in the skin can be removed by the application of a solution of 1 : 100 mercuric chloride until vesication results, when the powder grains can be picked out or allowed to exfoliate with the dry scabs of the vesicles. By this plan the discoloration can be much lessened.

Frost-bite.—This condition calls for prompt treatment. The white, tallow-like nose, auricle, or cheek should be at once gently, but steadily, rubbed with snow or ice *in a cold apartment* or in the open air, for the purpose of gradually thawing the parts. When this is effected, the patient may enter a moderately warm room, but should be kept away from the fire, and a wet alcohol dressing should be maintained in situ for some hours. By this treatment little trouble results beyond congestion and swelling, with some exfoliation of the epithelium and with an increased tendency to freezing on subsequent slighter exposures. *Per contra*, too rapid thawing leads to vesication, ulceration, and even superficial gangrene.—Pernio or chilblain, with reddened, itching, burning skin, and perhaps a vesicated surface, results from the sudden application of caloric to an area previously rendered anæmic by cold. The condition is essentially a vaso-constrictor paralysis of rapid development, and is at times difficult to overcome. The sudden entrance into a warmed apartment and the exposure of the parts to the warmth of an open fire, steam radiator, or hot-air register, is the usual cause.

Treatment of Pernio.—When it has been once produced the hyperæmia following frost-bite readily recurs under a similar exposure of lesser degree. The preventive measures mentioned for frost-bite, the administration of strychnia and ergot by the mouth or hypodermically, and the use of the constant galvanic

* The Wolfe graft consists of a detached portion of the whole thickness of the skin which is secured by sutures or by applying a compress over a freshly denuded surface or on a healthy granulating surface which has been carefully curetted to remove the granulation tissue which has not yet developed into new connective tissue. No fluid except decinormal salt solution should be employed throughout all these procedures. The detached graft should be at once transferred to a warm (not hot) decinormal salt solution, and while it is in the solution all the subcutaneous fat should be removed by scissors curved on the flat. Afterward the graft should be secured in position as suggested above, and dressed after the method of Thiersch for the first few days. No unnecessary delay should be permitted in removing the graft from its original to its new position.

current or of stimulating applications, such as alcohol, tincture of camphor, etc., for the purpose of exciting vaso-constrictor activity, may be tried, in the hope of thereby lessening the unsightly bluish-red coloration, the burning and itching when the parts become warmed after having been chilled from exposure, and the tendency to recurring vesication and even ulceration. Courtin, of Bordeaux, extols immersion of the affected parts (the foot, for instance) in a solution of hydrogen dioxide (3 to 6 volumes), reduced to this strength by the addition of a hot saturated solution of sodium bicarbonate. Whether compresses soaked in this preparation and frequently changed will accomplish equally good results in frost-bite of the face remains to be proved by a trial, and of such a trial the writer has as yet no knowledge. Patients should be warned for long periods, if not for life, to avoid immediate entrance from the outer air into a warm room, and not to approach a fire, after having been exposed in even moderately cold weather; otherwise the most careful treatment will often fail.

INFECTIONS OF THE FACE AND THEIR RESULTS.

Furunculosis.—Etiology and Complications.—A facial furuncle is chiefly of interest because it may prove to be the precursor of that fatal malady, facial carbuncle. Otherwise furuncles present no special peculiarities as to pathology, symptomatology, or treatment. The more superficial infections of the face caused by staphylococci—such, *e.g.*, as eczema, impetigo, acne, sycosis, etc —favor the development of an ordinary furuncle and its conversion into a carbuncle. Diabetes often serves as an underlying predisposing factor. Infection from what might be termed the normal epidermal staphylococci of the face is not the sole cause of either furuncles or carbuncle, as scratching by the fingers fouled with pus has been known to originate these troubles. Traumatisms of a simple furuncle located in close proximity to a hair follicle may, through migration of the germs inward along the hair shaft, serve to increase the trouble. Under these conditions the infective micro-organisms may advance by way of the lymph radicles of the skin and cellular tissue until a considerable area becomes involved, and then coagulation-necrosis and casting off of the central portion or "core" is likely to follow. This central slough is composed of the dead hair follicle, the associated sebaceous glands, and possibly some surrounding cellular tissue. The consequent healing occupies from ten days to several weeks. (See article on Abscess in Vol. II.)

Invasion of neighboring hair follicles or sweat glands by the germs in the discharges sometimes leads to repeated crops of furuncles, *i.e.*, to furunculosis.

Symptoms.—A small, ill-defined, congested indurated spot develops in the true skin, usually around the base of a hair. The induration tends to assume an acuminate form. It is tender and painful from the onset and continues to increase in size until a dense, slightly elevated, dusky-red area forms. Around this densely infiltrated area, which may reach an inch in diameter, there is considerable œdema. Usually, where a hair emerges from the acuminate swelling, slight suppuration appears in the course of a few days. When the epithelium is removed, a yellowish slough is seen—the "core,"—around and beneath which more or less free suppuration develops, until by the end of a week or ten days the slough separates. The little cavity which remains fills up rapidly and healing is effected. Sometimes suppuration does not take place, the hardened, painful, tender spot, after persisting for a number of days, gradually disappearing and leaving behind a reddened, discolored area for a considerable period. This is what is termed a "blind boil."

Diagnosis.—Very rarely, certain pustular syphilides resemble boils, but they pursue a chronic course, are painless, and are of a darker, duskier hue. When specific treatment is not employed they persist for long periods. A carbuncle is usually larger than the most pronounced boil, has more than one point of suppuration, is flattened and not acuminate, is painful but not noticeably tender, and is usually single.

Prognosis.—Unless some of the complications mentioned arise, the prognosis is good so far as the individual furuncle is concerned, but others are prone to develop in the neighborhood.

Treatment.—Strict asepsis should be aimed at, all scratching, handling, or attempts to "squeeze out the core" should be avoided, and the neighboring skin should be protected from contact with the pus. Early aseptic removal of the summit of the pustule, with extraction of the hair whose follicle is suppurating, will often abort the furuncle. If the infection is more widespread, freezing, followed by proper incision and the application of dry absorbent gauze to prevent infection of the surrounding skin, is the best practice. If the slough is nearly loose it may be removed, but without violence, because the danger of spreading the infection in this dangerous locality renders forcible removal of the slough a reprehensible practice. From the anatomical fact that the sweat glands are located in small depressions of the under surface of the corium, or more deeply still in the subcutaneous tissue, their invasion by pyogenic organisms leads rather to abscess than to a genuine slough. Spontaneous opening is claimed by some to be the rule, the dense induration that remains breaking down by a process of secondary suppuration; and for this reason incision is held to be the better plan of treatment.

Treatment by bacterial vaccines is alleged to be of great value.

As the formation of furuncles is often associated with a disordered state of gastro-intestinal digestion, it is important that due attention should be paid to this condition in those cases in which it seems to be present.

For both furuncles and the glandular type of abscesses the Bier method often serves an excellent purpose. This mode of treatment, however, is yet too much in the experimental stage to warrant unreserved commendation. It may be tried in carefully selected cases where the disease is not too diffuse. Certain precautions should be exercised in applying this method. To prevent infection of the surrounding skin a thick layer of some tenacious ointment—*e.g.*, diachylon ointment—should be applied. The cupping glass should be of such a size and form that it may be applied to the skin at a fair distance from the infected area. Enderlen recommends a daily séance of forty-five minutes, suction being used for five minutes at a time, with three-minute intervals of rest. The suction power should be increased gradually and only to the point where it is just sufficient to make the glass hold firmly. At the conclusion of each séance the protective ointment should be removed with ether or benzene, and an aseptic dressing applied. The daily séances should be maintained until the lesion is healed.

The opsonic theory and its consequent vaccine therapy are still too much in the experimental stage to warrant dogmatic statements, but the treatment is worthy of trial in obstinate furunculosis, carbuncles, and other infections due to pyogenic organisms. (See Vol. III., p. 593 *et seq.*, and Vol. IV., p. 959.)

Carbuncle.—A furuncle of the upper lip may be, and often is, the starting-point of the dangerous malady now under consideration. From one of the older names, anthrax, it is sometimes confounded with the disease caused by the anthrax bacillus. True anthrax can, and does, occur in this locality, and a description of it will be found farther on (page 436).

Facial carbuncle is a pyogenic inflammation of the skin and subcutaneous cellular tissue. It starts on the skin surface and later the integument is destroyed over isolated areas; or the affected tissue may slough away *en masse* from destruction of the subjacent blood-vessels, the result of the gangrenous inflammation of the cellular tissue in which the cutaneous blood supply is located.

Symptoms and Complications.—At the outset, especially when the disease starts as a furuncle, the swelling on the lip is acuminated, but later, through the lateral spread of the infection, the lip becomes densely infiltrated, forming an enormously thickened flattened mass. The deeply red, purplish skin is often riddled by ulcerated openings through which pus and, later, sloughs are evacuated, should the patient survive long enough. The skin openings result from the pus travelling along the lines of least resistance—*i.e.*, the columnæ adiposæ. In certain instances multiple abscesses perforate the mucous membrane, giving it a cribriform appearance. Owing to the absence of valves in the veins of the face, the blood of this region empties as readily through the superior ophthalmic vein as through the facial. Infective thrombo-phlebitis is apt to be the rule in facial carbuncle, so that, favored by the anatomical conditions just mentioned, infective sinus-thrombosis and meningitis, one or both, are among the common and fatal complications of this disease. The thrombo-phlebitis may involve the inferior facial vein alone, extending to the submaxillary region and the jugular vein, or the infection may pursue both routes—*i.e.*, the route by way of the superior as well as that by way of the inferior facial vein. Bacteriæmia is another not uncommon condition; it is due to the entrance of micro-organisms into the rich network of the facial lymph-vessels, whence they reach the blood. Traumatisms of the initial lesion—such, *e.g.*, as puncturing with needles, attempting to squeeze out the core, etc.—favor this last complication. Pyæmia alone, or in addition to the complications just mentioned, may occur, softening of the thrombi taking place from the action of the peptonizing ferments produced by pyogenic organisms, and from detached fragments of these thrombi entering the blood current and being lodged in the various organs. Soon after the dense, rapidly spreading infiltration of the lip has taken place and the skin has assumed a livid, vesicated appearance, the indurated, cord-like, thrombosed veins may readily be felt leading up to the inner angle of the orbit, or downward to the submaxillary region, or in both directions. Widespread œdema of the eyelids, cheek, and submaxillary region (one or all) rapidly supervenes. When the angular and superior ophthalmic veins are thrombosed, the clotting soon reaches the cavernous sinus, this condition being characterized by chemosis of the conjunctiva and by exophthalmos. The exophthalmos is not always limited to one side; in not a few instances it is bilateral. Symptoms of meningitis also develop, as a rule. When the thrombo-phlebitis is arrested before the sinus is involved, or when it progresses solely along the main facial vein, the orbital and cerebral symptoms are absent. Sooner or later marked systemic symptoms develop. Should bacteriæmia or pyæmia supervene, these will modify the clinical picture by their more or less characteristic symptoms.

Prognosis.—The prognosis depends upon the presence or absence of intracranial complications and the development or absence of severe bacteriæmia and pronounced pyæmia. Diabetes, alcoholism, and diseased conditions of the kidneys and other organs all influence the prospects for recovery. Unless early and efficient treatment is instituted the prospects for recovery are not good.

Treatment.—As soon as evidences of the malignant nature of the affection are seen, free incisions should be promptly made, regardless of the mutilation entailed. (These can be dealt with later by plastic procedures if deemed necessary.) The incisions are best made so as to divide the whole length of the free border of the lip, while others should pass off from this at proper angles so as freely to incise all the infiltrated area of lip and cheek. Opinions are divided as to the advantages accruing from the use of strong antiseptic solutions after incision, although it is possible that infiltration of the periphery of the area involved may prove useful, care being taken to avoid any dangerous dosage of any drug. Light packing of the incisions with iodoform gauze is of undoubted advantage.

Strong germicides applied to the wounds can hardly exert any effect upon the germs that are situated deeper in the tissues where the process is advancing, and they only tend to lessen the already enfeebled tissue resistance upon which the ultimate recovery depends. This resistance must be increased by the administration of proper food and stimulants (alcoholic as well as medicinal), by securing for the patient a proper amount of sleep, and by a free elimination of toxic materials. This last indication can best be fulfilled by increasing the secretions of the kidneys and skin, through the ingestion of large amounts of water by the mouth, by the use of enemata of normal salt solution introduced slowly into the rectum, or by subcutaneous injections of this solution. Saline purgatives or even laxatives sometimes prove of value as eliminants. It is improbable that the condition will often, if ever, warrant the employment of the Bier aspiration method, especially in view of reported results. Bacterial vaccines, if time permits, may possibly be of service.

Facial Gangrene.—Entirely independent of the condition termed gangræna oris, which attacks primarily the mucous membrane of the cheek and leads to widespread destruction of the soft and hard parts, ordinary gangrene, due to a mixed infection with saprophytic and pyogenic organisms, is sometimes observed in the face, where it produces the most frightful destruction of the tissues. This is well illustrated by the accompanying cut. (Fig. 155.)

FIG. 155.—Gangrene of the Face, Resulting in the Destruction of the Nose and Both Lips. It developed in a rachitic child in the course of an attack of scarlet fever. ("Cliniques Médicales Iconographiques," par Messrs. Haushalter, Étienne, Spillmann, et Thiry, Paris, 1901.)

Anthrax: Malignant Pustule; Charbon.—Anthrax—a disease, as has already been pointed out, which superficially resembles ordinary carbuncle—is sometimes located upon the face, but this is not the result of an ordinary pyogenic infection, but of the inoculation of the Bacillus anthracis. While it is a rare disease in this country, it is not uncommonly met with on the Continent, in South America, and in the Far East. (See Vol. II., p. 48.) Butchers, those who handle raw hides, curriers, and wool and hair sorters are the usual victims, the infection being conveyed to the face by scratching or handling some open lesion. Farmers, veterinarians, and pathologists, who are exposed in a lesser degree, also sometimes contract the disease. Infected food might possibly prove a source of infection, as it has sometimes done in the case of other diseases (it being assumed that a cracked lip furnishes the necessary point of entrance for the infection). Occasionally mosquitoes and flies, which have fed upon animals dead of anthrax, bite and thus inoculate human beings. Both the œdematous and the circumscribed carbuncular forms of anthrax attack the face, but the latter is the more common variety; sometimes there is a combination of both. While the etiological factor is the Bacillus anthracis, secondary pyogenic infection sometimes complicates and modifies both the symptoms and the course pursued by the disease.

Symptoms and Course.—The period of incubation lasts for a period varying from a few hours to three days, and is followed by malaise, slight hebetude,

Fig. 156.

Fig. 157.

Figs. 156 and 157.—Case of Anthrax of the Face. The first photograph (Fig. 156) was taken when the disease was at its height: the second one (Fig. 157), just before the patient left the hospital, practically well. (Schwarz, in *Deutsche Zeitschrift für Chirurgie*, March, 1908.)

chilliness, slight fever, nausea and vomiting. Then usually there appears a single itching red spot, in the midst of which a bluish vesicle filled with bloody serum quickly develops and ruptures, revealing a blackened slough underneath. Sometimes, instead of a single red spot, several make their appearance. The skin immediately adjacent to the slough is red, brawny, and elevated, and still farther away there is pronounced œdema of the parts. The sloughing process, although it may cause extensive destruction of tissue when several foci are present, is usually confined to an area about 2 cm. ($\frac{4}{5}$ in.) in diameter. Upon this rests a blackened scab, beneath the edges of which bloody serum, not pus, exudes, unless secondary pyogenic infection has occurred.

The most typical cases soon show a more or less perfect ring of secondary vesicles around the primary focus, and these lesions undergo the same changes as those which take place in the primary one. In other cases, however, the secondary vesicles are irregularly disposed over the infiltrated area. The patient is singularly free from pain; the regional lymph nodes become early involved and are tender; and the adjacent and overlying tissues are œdematous. The œdematous form, "*œdème charbonneux,*" commences as a doughy swelling most commonly located in the upper palpebral tissues. An enormous, widely spreading, semi-translucent, œdematous swelling ensues, and this in turn is followed by extensive necrosis of the tissues, if the patient does not succumb in the mean time to generalized infection.

In all forms of the disease the initial slight fever and hebetude become more pronounced with increase in the gastric symptoms. In the milder cases, where the infection remains strictly local, the necrotic areas desiccate and are cast off, leaving an ordinary granulating surface which eventually cicatrizes. Meanwhile, the constitutional symptoms recede and finally disappear. In the more severe cases death results from bacillæmia, perhaps reinforced, in the more slowly progressing ones, by secondary infection; but in the worst forms of anthrax, the fatal result occurs too soon to be ascribed in any degree to pyogenic processes, death being due rather to the action of the Bacillus anthracis and its toxins in the blood and tissues. The worst infections terminate in death in from two to three days, while in the average case, with generalized infection, the patient lives for from four to six days.

In the malignant cases chills, high fever, pains in the head and extremities, and marked exhaustion rapidly supervene, the vomiting becomes more frequent and more severe, the ejecta finally becoming bloody; and the spleen, in some cases, undergoes enlargement. Locally, the infiltrated, congested area around the necrotic focus becomes more and more cyanotic. Cold sweats with subnormal temperature, dyspnœa, and increasing somnolence which deepens into coma announce the approach of a fatal termination. In rare instances delirium and convulsions have preceded death, which may also occasionally be due to syncope, or may result from œdema of the glottis when the tissues of the neck participate in the disease.

Complications.—Aside from the systemic infection, œdema of the glottis and extensive destruction of the eyelids and other soft parts leading to secondary deformities are the only complications of moment; although, when secondary pyogenic infection occurs, any of the complications of a suppurating wound are possible.

Diagnosis.—This must rest at the outset, in the typical cases, on the central blackened slough, the surrounding dense infiltration and œdema, the presence of a ring of secondary vesicles, the almost complete absence of local pain and of all suppuration, the dense adhering sloughs, and the rapid development of a typhoid condition. In those cases in which the carbuncular symptoms are not pronounced, and in the cases of œdematous anthrax which run a rapidly fatal course, the diagnosis must be made by exclusion. All doubts, however, as to the nature of the disease may often be promptly removed by the inoculation of a mouse with some of the fluids, or by a microscopic examination of cover-glass smears, whenever wound secretions are obtainable.

Prognosis.—Although the prognosis is in all cases grave, because of the risk of systemic infection, the chances of recovery are fairly good where the disease is limited to an area of skin which is situated favorably for effective local treatment. When the opposite conditions prevail, as in the purely œdematous form of the disease, a fatal termination is to be anticipated, although now and then a recovery does take place even in these cases.

Treatment.—The treatment resolves itself into removal of all infected tissues by the knife or other destructive agents; and, when all the diseased tissues cannot thus be eradicated, and when the growth of the bacilli cannot be scientifically inhibited, it is well to employ, in addition to the measures named, some germicidal substance. The injection of ninety-five-per-cent carbolic acid around and beneath the base of the diseased area is really as destructive as are the knife and actual cautery. The knife, and also to a slighter degree the cautery, involve the risk of generalizing the bacilli and may unnecessarily mutilate the patient; and yet the free use of the knife or cautery, or both, is in some cases the best practice, the other measures suggested being employed later as succedanea. Where widespread destruction of the infected tissues is not resorted to, the best results will probably accrue from the infiltration of the surrounding, subjacent, and diseased tissues, three or four times daily, with a three-per-cent carbolic-acid solution, and from maintaining the temperature of the part above 45° C. (113° F.), by applying outside a dressing wet with 1 : 1,000 mercuric bichloride solution, a sterilized poultice at 50° to 55° C. (122° to 131° F.), which must be changed every ten minutes. This degree of heat effectually inhibits the growth of the anthrax bacillus, which is said to cease growing at 42°–45° C. (108° to 113° F.).

The administration of nutritious food and alcoholic stimulants, the securing of proper sleep, and the paying of proper attention to the eliminating organs are all measures that serve a useful purpose in increasing the resistance of the tissue cells. Quinine and carbolic acid given internally, in what would seem to be dangerous doses, have apparently proved beneficial in certain cases in which local treatment could not be effectively employed. Of course, the administration of large doses of carbolic acid internally, as well as the administration of weak solutions of the acid by the infiltration method, must be carefully watched, lest poisoning result.

Facial Abscesses.—Owing to the richness of the blood supply of the tissues of the face their resistance is such that ordinary infected wounds rarely give rise to serious phlegmons. This is far from true, however, for deep punctured or lacerated wounds, especially those which extend into the accessory nasal cavities. Gunshot wounds, especially those inflicted by birdshot, so devitalize both the hard and the soft tissues that serious, deep-seated suppuration would occur oftener than it does were it not for the free drainage afforded by the widespread destruction of the tissues. Should saprophytic organisms gain access to the wound, true gangrene may follow. Buccal, submaxillary, and submental abscesses are often due to alveolar abscesses caused by carious teeth, and to periostitis, caries, and osseous necrosis of the jaws following bone infection. The possible action of mercury or phosphorus in producing osseous disease must not be forgotten. Another possible cause of an abscess in the cheek is pyogenic infection of the lymph nodes lying upon the buccinator muscle near the angle of the mouth, through which nodes passes some of the lymph from the nose and lower eyelid.

Suppuration initiated by periosteal or osteal infection of the lower jaw may occasionally reach the temporal region by the travelling of pus along the inner surface of the masseter. Again, infection of the deep tissues or deep lymph nodes, in whatsoever manner caused, may start a deep-seated suppuration which in turn gives rise to a thrombo-phlebitis of the pterygoid plexus of veins; or the pus may push its way between the pterygoid muscles, the abscess pointing in such cases either below the zygoma or above it in the temporal fossa. Clinically, such an abscess may present features of a malignant neoplasm or of actinomycosis, as one of the author's recent cases has shown.

The possible evils of thrombo-phlebitis of the pterygoid plexus are not confined to the regions mentioned, for the process may extend to the ophthalmic vein and thence to the cavernous sinus, inducing fatal pyæmia, septicæmia, or meningitis. When the thrombotic process becomes limited to the orbit, abscess is certain to result in this cavity.

Diagnosis.—This must depend, as in abscesses in other parts of the body, upon the local and constitutional evidences of an infective process leading to the formation of a tumor or thickening which, after reaching a certain bulk, begins to soften at some point until fluctuation becomes discernible. When the tumor is deep-seated, the marked œdema or the obscure bogginess, coupled with leucocytosis, should suffice; or aspiration may be resorted to when the condition closely simulates a neoplasm, as it sometimes does.

Treatment.—Free incision and drainage constitute the important part of the treatment. In dividing the superficial tissues the surgeon should make the incision in such a direction that the knife will not encounter the main branches of the facial nerve, but will pursue a course parallel to that taken by its filaments. Due regard must be paid to the location of the larger blood-vessels. If the tissues are incised in the direction pursued by the normal creases and wrinkles, the subsequent deformity will be materially diminished.

Salivary-Duct Fistula; Salivary Fistula.—The latter term is employed to denote simply a fistulous opening through which saliva escapes upon some part of the cutaneous surface of the face, without regard to the source of such flow;

but, when the fistulous opening communicates directly with Stenson's duct itself, the condition is termed salivary-duct fistula.

Etiology.—Such an opening may be established as the result of a traumatism or of operative interference, or it may owe its existence to a sloughing process. The establishment of an external fistulous opening as a result of operative interference with the duct of the submaxillary gland is very unlikely to occur, and yet such an event is anatomically possible.

Congenital forms have been reported. Abscess of the duct perforating externally, sloughing of the duct and of the adjacent part of the cheek, carcinoma, syphilis, tuberculosis, and the acute form of gangrene called noma may all in rare instances cause salivary fistula, but traumatism is unquestionably by far the most common etiological factor.

Temporary fistulæ are not unusual after injury or operation in the parotid region, but it is rare indeed for them to remain open beyond at most a few months. When such a fistula obstinately refuses to heal, it is apt to be due to a wound of the duct a short distance from its origin in the substance of the gland itself.

Symptoms.—Although a salivary fistula is not a serious condition, its existence may prove a source of considerable annoyance to the patient through the almost constant flow of saliva—a flow which is very active whenever he ingests food—and also through the eczema of the cheek which is ordinarily associated with such a fistula.

The fistula presents the following appearance:—A short, very narrow tract is found opening, on the surface of the cheek, in a minute teat of granulation tissue, from which a varying amount of perfectly clear fluid exudes. This fluid is more abundantly emitted during a meal, and chemical and physiological tests prove it to be saliva. A further characteristic is that saliva does not enter the mouth on the injured side, which is dry or at least not normally moist. In some cases outlying parotid lobules lead to fistulous openings at some distance from the usual sites, or the unusual location of the opening may be due to the fact that the suppurative process has created a long fistulous channel. Infection spreading from the fistula sometimes leads to parotitis.

In the case of a fistula of Stenson's duct the symptoms are, as a rule, essentially the same as those already mentioned. The distance of the duct from the surface usually admits of only a short sinus, but sometimes there is a small cavity in the tissues between the skin orifice and the actual opening in the duct. The distal remnant of the duct often atrophies and the papilla contracts, rendering the passage of the finest probe difficult, if not impossible. This is one of the chief reasons why a spontaneous cure is impossible, and that an operation has to be done. The proximal end of the duct usually retains very nearly its normal calibre, however difficult it may be found in some cases to pass a probe, owing to the abnormal course pursued by the duct. Sometimes there are two or even many openings. The amount of saliva lost from a fistula of Stenson's duct is considerable, as may be inferred from such statements as "seventy grams were collected in fifteen minutes from one patient" and "several cupfuls in twenty-four hours" from another.

Diagnosis.—A salivary fistula can be mistaken only for a lymphatic fistula. The distinguishing characteristics are these: in the case of a salivary fistula the amount of fluid secreted is greatly increased during mastication, while in a lymphatic fistula no such increase takes place. Then, in the next place, a chemical examination reveals material differences between the two fluids.

In determining whether the fistula is in direct communication with Stenson's duct or whether it springs from the immediate vicinity of the parotid gland, it should be remembered that in the former case the opening will be found in front of the masseter muscle, and that the probe introduced into this opening may be pushed for some distance upward along what seems to be a canal before it meets with resistance. Furthermore, it will be noticed that in most cases a greatly lessened amount of saliva enters the mouth on the side of the fistula.

Prognosis.—Anatomically, the duct is divided into the buccal, masseteric, and glandular portions, and the chances in favor of recovery may be stated in the same order. Fortunately, the majority of fistulæ concern the buccal portion, where operative intervention is most effectual. The degree of narrowing of the distal portion, the fact that the mucous membrane and the skin have become united, and the nature of the causative factor (whether the fistula was produced by traumatic or by infective destruction of the tissues), are all matters that bear upon the prospect of failure or of success. The absolute impermeability of the distal extremity of the duct cannot always be affirmed from the mere fact that a fine instrument (such as the eye end of a needle) cannot be passed. But if, by injection under some pressure from above, a solution of methylene blue fails to appear in the mouth, or when, in the presence of a patent papilla, the same procedure fails to force the colored fluid through the fistula, total obstruction may be confidently affirmed.

Treatment.—The measures which may be adopted for the relief of a salivary fistula will vary not only according to the condition of the parts, but also according to the location of the lesion,—whether it is in connection with Stenson's duct, in front of the masseter muscle, or whether it communicates with the parotid gland itself or with a duct near its point of origin in the gland. In the latter case it may be found sufficient to cauterize the walls of the orifice occasionally with the galvano-cautery, introduced cold and then brought to the proper degree of heat; or, in the place of the actual cautery, a pointed stick of silver nitrate may be employed. In more obstinate cases it may be necessary to freshen the edges of the opening and then to apply sutures. But, when a considerable area of skin has been destroyed through ulcerative action or through sloughing, a plastic operation alone will suffice to remedy the defect.

In the treatment of a fistula located in front of the masseter muscle, operative interference is necessary and should have for its object the transference of the end of the duct from the outside to the buccal side of the mouth and the maintenance of the duct in this position until firm union shall have been secured on the skin side of the fistula. Where both sections of the duct are patent, the effort should be made to suture the ends together with fine catgut after freshening their surfaces. The non-operative methods of treatment described above should be given a fair trial, for months if necessary before resort is made to the knife.

In appropriate cases—*i.e.*, where both proximal and distal portions of the duct are patent and where there is only a moderate amount of scar tissue—exposing the duct, freshening the tissues by excising the scar, suturing the edges of the duct wound with catgut, and superimposing a flap secured from the tissues of the cheek, may be attempted. Even an end-to-end approximation has been successfully effected.

As to the further details of the operative work required, it may be stated that when the proximal end is of sufficient length it should be dissected out and, after a special incision has been made through the buccal mucous membrane (provided this has not been already done as a necessary part of the freeing of the duct), the extremity of the latter should be carefully secured to the mucous membrane by horse-hair sutures, and the cheek wound closed by suturing the margins of the freshened surfaces or possibly by employing a plastic flap. In otherwise inoperable cases, when the cheek wound cannot be approximated or a flap with an attached pedicle be secured, it may be possible to secure a successful result by utilizing a Wolfe graft after the duct has been transferred to its place in the mouth.

When the foregoing procedure is impracticable or for any reason undesirable, a very simple operation is often successful in re-establishing a free opening into the mouth, after which the external opening spontaneously heals or a plastic operation can be done. This operation may be described as follows:—Pass one end of a stout silk thread, armed with a needle at each end, through the fistula into the mouth. Then take the needle on the end outside the cheek and pass it also through the fistula, causing its point to emerge some little distance from where the first needle pierced the buccal tissues. In this way a small portion of the cheek, about one-third of an inch in breadth, will be included in the loop of the suture, and when the thread is tightly tied the tissues embraced will slough out, leaving a free opening for the passage of saliva into the mouth. Other methods of effecting the same end—*i.e.*, to render it easier for the saliva to reach the mouth than to pass along the fistula—have been devised and successfully instituted. Thus, for example, some modification of Desault's operation (see Fig. 156) may be done. Kaufmann's method is to introduce a small trocar and cannula through the cheek into the mouth, going as far as possible along the course of the duct, and in a direction both forward and inward. A fine piece of India-rubber tubing is next inserted into the cannula and passed into the mouth; the cannula is then withdrawn, and the outer end of the rubber tubing is cut off obliquely and so arranged that the saliva will flow directly into the tube and so into the mouth. This is on the plan of the original Richelot operation (see Fig. 159). The tube is gradually shortened at both ends, and after about ten days or a fortnight it can be removed entirely. The external wound heals promptly. As regards general measures, in cases of both types of salivary fistula, it is well to enjoin upon the patient the importance of abstaining from the use of stimulating foods and condiments, and of making the least possible use of his jaws, as in speaking and chewing.

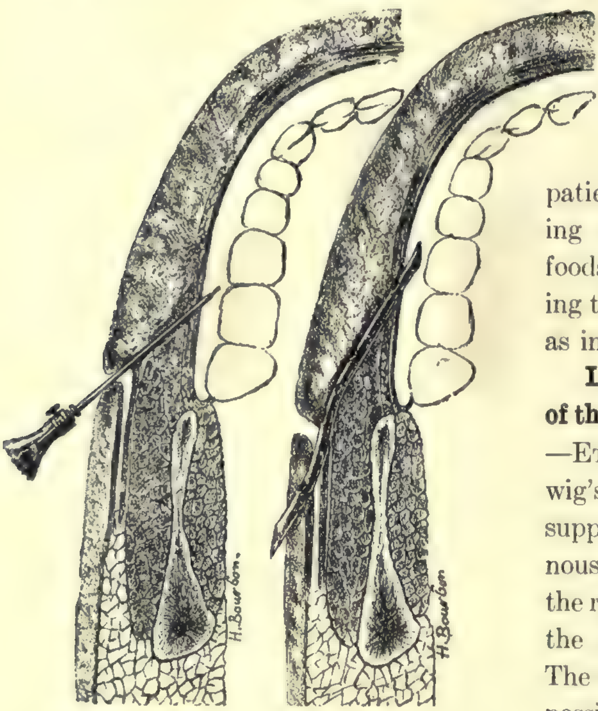

FIG. 158. FIG. 159.

FIG. 158.—Desault's Method of Operating for Salivary Fistula. A trocar is carried forward and inward from the opening of the fistula to a point opposite the second molar tooth. (Duplay et Reclus, "Traité de Chirurgie," V.)

FIG. 159.—Richelot's Method of Operating for Salivary Fistula. A rubber tube is so inserted that one end projects slightly into the mouth; the other end is then so cut obliquely that the saliva will flow directly into the tube, and so into the mouth. (Duplay et Reclus, "Traité de Chirurgie," V.)

Ludwig's Angina; Inflammation of the Submental Connective Tissue. —ETIOLOGY.—By the term "Ludwig's angina" is meant an acute suppurative, at times even a gangrenous, periglandular inflammation in the region of the submaxillary gland, the gland itself remaining intact. The infection, in these cases, may possibly arrive by way of the submaxillary lymph nodes, but more often it reaches the periglandular space from a lesion of the oral mucous membrane, from a carious tooth, or perhaps from an inflamed tonsil. While young children may be attacked, the disease is most common in males between twenty and thirty years of age. It has been alleged to have been observed in epidemic form.*

SYMPTOMS.—The disease is ushered in by a chill, which is followed shortly

*Some writers include under the term "Ludwig's angina," all forms of cervical cellulitis which involve the tissues of any portion of the submaxillary region. The description here given, however, is of a disease which seems to be somewhat different from, although closely akin to, infective cellulitis of the upper cervical region. It is probably different in origin, and certainly is in the course which it pursues, and it imperatively demands early and efficient treatment by free incisions, which is not true of any other variety of cervical cellulitis.

by high fever and severe constitutional symptoms. In some cases the chill is preceded by a toothache, an ulcer of the mouth, or an apparently trivial sore throat. A slight swelling, somewhat tender on pressure, appears on one side beneath the chin. The swelling and œdema rapidly extend, pushing up the tongue and causing the submental tissues to protrude. The denseness of the infiltration prevents opening of the mouth, chewing, or even swallowing. Dyspnœa is complained of even in the absence of true œdema of the glottis, the most dangerous of the earlier complications. When incision is delayed, widespread suppuration and sloughing are apt to take place, and death may occur within a few days from sepsis, the body temperature becoming higher and the constitutional symptoms more severe. In untreated, milder cases an abscess forms and may evacuate itself into the mouth or externally. The skin remains unaltered for the first two or three days, but after that it becomes œdematous.

Diagnosis.—The disease might possibly be mistaken for a simple periostitis of the jaw or for an ordinary suppurative process external to the dense submaxillary fascia. In the former affection the swelling is primarily connected with the bone and tends to extend up into the face and not in the direction of the submental region; in the latter, the floor of the mouth is not elevated, as it is in Ludwig's angina. Furthermore, in both of the conditions mentioned the local and constitutional symptoms are less pronounced.

Prognosis.—The prognosis is grave, yet with early energetic treatment most patients recover.

Treatment.—Early free incision through the skin, platysma, and possibly some fibres of the mylo-hyoid muscle, should be made parallel to the jaw. This had best be done as soon as severe constitutional symptoms are present, before any recognizable collection of pus has formed. Later, when a distinct abscess is present, the making of such an incision is still more imperative. It is better not to divide the deeper tissues with the knife, but to employ, instead, Hilton's method. According to this method, the superficial incision is first made and then, by means of a boring motion, a grooved director is forced down into the collection of pus or into the very centre of the infected tissues. Then a narrow-bladed, closed hæmostat is pushed along the groove of the director into the abscess cavity (or into the midst of the infected area), and, after it has reached this point, its blades are opened as widely as the resistance of the tissues will permit and the instrument (still with the blades separated) is withdrawn. In this manner all danger of dividing one of the larger blood-vessels is avoided and a free channel for drainage is provided. If it should be found necesary, a counter-opening may be made at any time. When œdema of the glottis makes its appearance, intubation or tracheotomy will be found necessary.

Cellulitis of the Orbit.—Cellulitis of the orbit may be confined to one side or it may be bilateral, and it may pursue an acute, subacute, or chronic course.

Usually it ends in suppuration, but in some cases resolution takes place, without the formation of pus. The dull pain, swollen lids, slight exophthalmos, and double vision may sometimes all be present without distinct constitutional symptoms, and these are the cases in which resolution sometimes occurs. Too often the symptoms of orbital abscess, as given under that caption, supervene with greater or less rapidity.

Orbital Abscess.—Etiology.—Mention has already been made, on a preceding page (p. 440), of the fact that thrombo-phlebitis may, as a complication of facial erysipelas, involve the tissues surrounding the eyeball and result in orbital abscess. Among the remaining causes of this condition the following deserve to be mentioned:—Penetrating wounds involving the orbit, especially when foreign bodies remain lodged; the extension of infective processes from the eyelids, from the periosteum (as after fracture of the malar bone), or from one of the large neighboring cavities (antrum, the sphenoidal or ethmoidal cells), as after a fracture of the upper jaw, or during the course of a suppurative disease of one of those cavities; and pyæmia, especially where this is dependent upon some pathological disturbance connected with the puerperal condition. When orbital abscess complicates any of the eruptive fevers or the grippe, it is due either to a spread of the infection from some of the accessory nasal sinuses that are in close proximity to the orbit, or to the lodgment of emboli composed of the pyogenic organisms themselves.

Symptoms.—At an early stage of the disease there is pain in the orbit and in the frontal and temporal regions, with distinct constitutional symptoms, and very soon œdema of the eyelids, with chemosis of the conjunctiva, makes its appearance. Still later, there is exophthalmos with more or less fixity of the eyeball and impaired vision, and from this time onward the cornea remains in some degree constantly uncovered. As the inflammation and subsequent suppuration may not be uniformly disposed around the globe, the eye may be thrust downward, upward, or outward rather than directly forward, although the last is the rule.

Diagnosis.—In the acute form, some one of the precedent causative conditions—such, for example, as facial erysipelas, thrombo-phlebitis of the facial veins, or a traumatism of the orbital tissues or the surrounding bony wall—usually precedes the localized manifestations; and if constitutional symptoms develop, or if they recrudesce after diminishing or disappearing, there should be very little doubt about the correctness of the diagnosis, even before fluctuation becomes apparent. However, if, notwithstanding the presence of these symptoms, some doubt remains in the surgeon's mind, it is permissible for him to employ an exploring or an aspirating needle.

In a case of chronic orbital abscess the symptoms may be much less characteristic, and it will then be correspondingly difficult to make a diagnosis. In many cases it is known (or at least strongly suspected) that disease of one of the neighboring accessory nasal sinuses, or of the osseous orbital walls, preceded the development of the exophthalmos. Under such circumstances it seems more in accordance with the pathological facts to attribute the protrusion of the eyeball to the pressure caused by a collection of pus rather than to the presence of an hydatid cyst, an orbital aneurism, or a thrombosis of the cavernous sinus. The differential diagnosis of abscess from chronic orbital tumors such as cysts, fibromas, cavernous and simple lymphangiomas, lipomas, and various types of sarcomas, from innocent or malignant tumor of the lachrymal gland and from meningoceles, must be sought in other sections of this work. (See articles on "Surgery of the Head" and "Surgery of the Eye" in this volume.) The detection of a circumscribed tumor displacing the eyeball *away* from it; the recession of the ball when the carotid artery is compressed, especially if local pressure causes the eyeball to recede into the orbit; and, possibly, the detection of pulsation and an aneurismal bruit, indicate plainly that the exophthalmos is not due to a chronic abscess. In some cases of soft solid or cystic growths it may be found necessary to resort to an exploratory aspiration in order to verify the diagnosis.

Complications.—Unless the pressure upon the eyeball from behind is soon relieved the cornea, continually exposed because the lids cannot close over it, soon becomes damaged or may even undergo serious ulceration. Disturbances of vision occur independently of any corneal changes, the relative immobility of the eyeball and its partial dislocation rendering convergence of the optic axes difficult or impossible. Interference with the circulation of the retinal vessels may produce an œdematous exudation or a hemorrhage into the retina. Panophthalmitis and inflammation of the optic nerve, followed by atrophy, are also possible complications. The most dreaded sequel is extension of the inflammatory process to the meninges, to the cavernous sinus, or to the brain tissue itself, the involvement of which in the disease results in the formation of a brain abscess. Probably in most instances the intracranial complications are brought about by an advancing infective thrombo-phlebitis. It must not be forgotten, however, that thrombosis of the cavernous sinus may occur without any recognizable primary involvement of the orbital tissues or veins. For example, the source of infection may be located within the area drained by the facial vein or by those vessels which return blood from the accessory nasal sinuses.

Prognosis.—The prognosis of orbital abscess is uncertain, being dependent upon the presence and severity of the complications mentioned. When the disease is bilateral and when it results from erysipelas or an infective thrombophlebitis a fatal result is probable. When nothing but suppuration within or around the cone of the recti muscles exists, the danger to life need not be considered serious, although vision may be impaired or lost from some of the complications detailed above. When the disease is of pyæmic origin, the prognosis depends upon the pyæmic condition, not upon the orbital abscess alone, although extension to the meninges and cavernous sinus, with fatal results, is probable.

Treatment.—Early incision should be made through either the upper or the lower eyelid, according to the direction in which the eye is dislocated, in order to prevent extension of the disease backward, secondary changes in the eye, or damage to or destruction of the cornea from constant exposure to traumatism and accidental infection. The incisions should be made parallel with and close to the bony margin of the orbit, with the object of lessening the tendency to ectropion that results from contraction of the cicatrix. Foreign bodies, if present, should be removed, even if an osteoplastic resection of the outer wall of the orbit becomes requisite; and if the abscess or the cellulitis originates from nasal-sinus disease, or if dead bone is present, those conditions must be appropriately dealt with primarily or secondarily.

Thrombosis of the cavernous sinus produces symptoms not unlike those of cellulitis or abscess of the orbit, but, in addition to the proptosis, the œdema of the eyelids, the chemosis of the conjunctiva, and the cloudiness and anæsthesia of the cornea, an ophthalmoplegia, due to slowly increasing pressure on the third, fourth, and sixth nerves, gradually develops, the ophthalmoscope revealing engorgement of the retinal veins and neuroretinitis. (For the general and cerebral symptoms, the reader is referred to p. 250 in the present volume.)

Osteomyelitis of the Malar Bone.—Etiology.—A few cases of acute infectious osteomyelitis and periostitis of the malar bone, of hæmatogenous origin, have been reported, but usually such conditions result from extension by continuity from an open trauma of the skin or mucous membrane. Infected gunshot and other severe osseous injuries of this or of other related bones may also produce necrosis of the malar bone. Thus, a suppurative osteoperiostitis of the upper jaw, usually dependent upon phosphorus necrosis but sometimes purely pyogenic in character, may spread to the malar bone. The possibility of bone trouble starting from within must also not be overlooked, for the body of the malar bone at times contains air-cells that communicate with those in the mastoid process or with the antrum of Highmore.

Symptoms.—The symptoms differ in no essential respects from those of osteomyelitis attacking other bones.

Prognosis.—Chronicity characterizes malar necrosis, and the deformity ultimately caused by the disease is slight or marked according to the size of the resulting sequestra.

Treatment.—The treatment consists of incision and drainage, combined with removal of any sequestra or carious bone that may be present.

Facial Erysipelas. — Etiology.—Erysipelas often originates from some concealed trivial lesion of the mucous membrane of the nose or mouth, the disease later reaching the cutaneous surface by extension. An open atrium of infection at some part of the skin or mucous membrane is requisite for the entrance of the Streptococcus pyogenes into the superficial network of the lymph vessels, and from this point, where it finds a favorable habitat, it extends widely. Primarily a non-pyogenic cutaneous lymphangitis, the erysipelatous process may extend to the deeper tissues.

It is believed that secondary infection by germs resident upon or in the skin accounts for nearly all, if not all, cases of suppuration in uncomplicated erysipelas. It is alleged that in exceptional cases the infection follows two unsuspected routes from the naso-pharynx to the face, viz., the ductus ad nasum and the Eustachian tube. Streptococcus tonsillitis—that affection which is so common—may be the origin of an erysipelatous outbreak, as in cases observed by the author.

Cutaneous erysipelas may secondarily invade the contiguous mucous membranes. Injuries of and operations upon the face involving trauma of the mucous membrane of the nose or mouth occasionally give rise to facial erysipelas, for no technique, however perfect, insures against streptococcus infection, these organisms being habitually present in the tonsil crypts and adenomatous tissues of a chronically inflamed naso-pharynx.

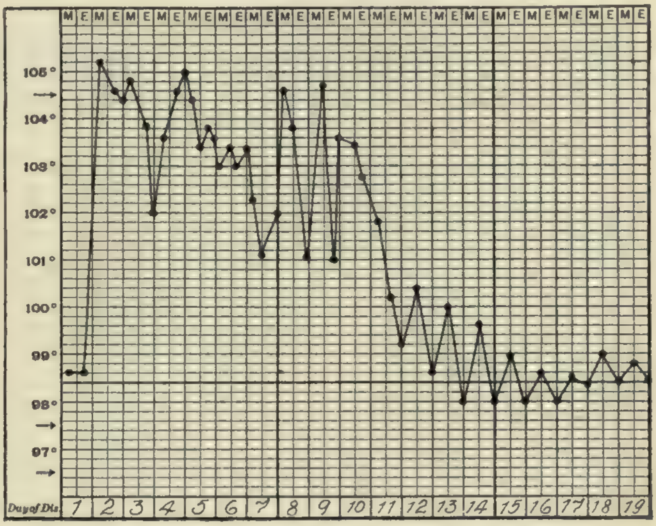

FIG. 160.—Maximum Temperature Reached in Eight Hours.

PROGNOSIS. — The prognosis is favorable in the young and robust, being only dangerous — aside from complications—in chronic alcoholics and those with damaged kidneys and livers.

COMPLICATIONS. — Infective meningitis may result from thrombo-phlebitis or thrombo-lymphangitis. If the tissues near the glottis become involved, dangerous œdema may result, and a peculiar form of pneumonia is not uncommon. Secondary infection by pyogenic skin organisms may originate suppuration, which is usually local and insignificant, but deep-seated orbital abscess is not an unusual outcome of the disease, with the possible extension of infective trouble to the meninges and the risk of damaged vision or total destruction of the eye. These deep-seated processes are favored by the necrosis of the skin of the eyelids from strangulation, due to the accumulation of the exudates in the loose palpebral tissues. Pyæmia is not unknown, and even bacteriæmia occurs, either of which complications may account for the numerous metastatic foci that occasionally develop as sequelæ of erysipelas. The regional lymph nodes are always enlarged and tender and they sometimes suppurate, the germs reaching them directly by way of the lymph current. The tenderness and enlargement of the lymph nodes may sometimes be recognized before any cutaneous lesion is detected.

Repeated attacks lead to partial blocking of the lymphatics, so that much of the exudate organizes, producing thickening of the skin of the nose, eyelids, cheeks, and lips; this has sometimes been considered to be one of the varieties of facial elephantiasis.

Symptoms.—Malaise, headache, nausea, and sometimes vomiting precede the chill which usually ushers in the attack, although, when fever from other

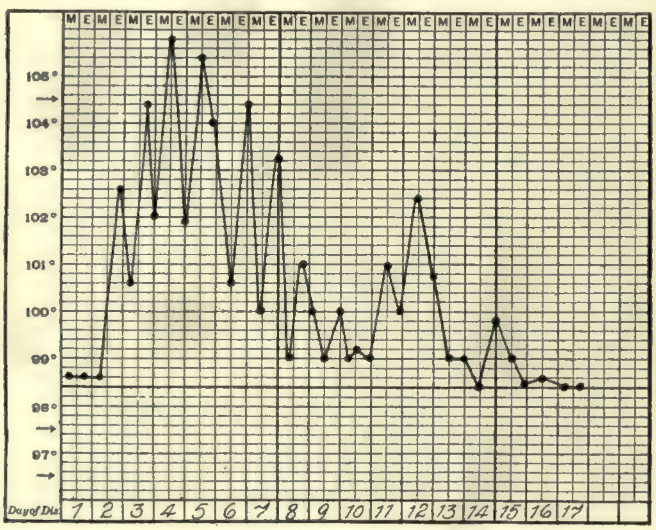

Fig. 161.—Maximum Temperature Reached only Gradually, with a Similar Subsidence of the Fever.

causes is already present, a rigor may not occur. The temperature rapidly increases, sometimes attaining its maximum in a few hours (Fig. 160), but usually it shows a morning remission while still climbing slowly from day to day until 103°, 104°, 105°, 106°, or even 107° F. is reached. (Fig. 161.) In very mild cases the temperature is sometimes so slightly elevated as to cast suspicion upon the diagnosis. (Fig. 162.) The temperature now either gradually declines until at the end of ten or twelve days the normal is reached, or rapid defervescence may take place, the thermometer registering the normal or nearly normal temperature in twelve or fifteen hours after the maximum has been attained. If a fresh extension of the disease then occurs, chills or chilliness with a sharp rise of temperature will occur, but these recurrences usually pursue a shorter course than the primary attack. In children a convulsion may replace a chill or rigor. The pulse may reach 120 or higher in the typhoid forms and is always rather weak.

The tongue is covered with a thick, tenacious, yellow coating. Swelling and tenderness of the regional lymph nodes usually precede any local manifestations. Heralded by a sense of tension with burning pain, more often near the root of the nose, on one cheek or on one ear, there is detected an irregular reddened patch which rapidly spreads either in all directions or often almost solely in one. The advancing border, however irregular in outline, is always sensibly elevated above the healthy skin, while at those points where the inflammation has ceased to extend the redness gradually fades into that of the surrounding parts. Blebs and bullæ soon form; they are filled with serum variously tinted with blood, and if they are ruptured they dry up into thin, dark-brown scabs. Œdematous swelling of all the parts involved rapidly supervenes until in bad cases the individual becomes unrecognizable. The loose cellular tissue of the eyelids permits of extreme swelling, sometimes so great as to produce connective-tissue strangulation and necrosis of the skin; the nostrils become partially occluded; and even the lower jaw is restricted in its movements by the inflammatory infiltration of the cheeks. Of course, secondary pyogenic infection may occur, with ulceration or cutaneous abscesses. Restlessness, headache, delirium, with periods of somnolence, are present in bad cases, while in the worst a typhoid state develops, with dry brown tongue, frequent pulse, vomiting, diarrhœa, etc. As the fever and swelling subside, exfoliation of the epidermis occurs, leaving redness which sometimes lasts for weeks.

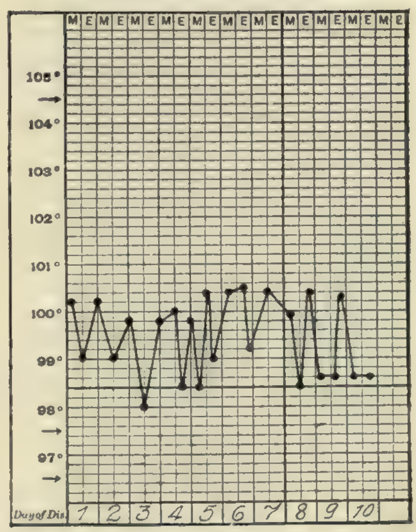

Fig. 162.—Very Slight Elevation of Temperature which Remained at about the Same Point until Defervescence rather Suddenly took Place.

Diagnosis. — Erythema, drug eruptions, and rashes from ptomaïn-poisoning are the only conditions likely to be confounded with facial erysipelas. Ptomaïn rashes are apt to be generalized, and they have no elevated, sharply cut margins; the widespread œdema is absent, and what is present is of short duration; while vesication does not occur. Erythema lacks the elevated, sharply defined borders, and the redness fades gradually into the hue of the surrounding skin. Drug erythemas are either confined to the areas to which the application is made, or appear—unlike what is observed in erysipelas—at points far distant from the wound. Still further, constitutional symptoms are absent in drug erythemas. When the cutaneous reddening is the result of an inflammation of the subjacent bone or soft parts, local conditions which usually can be detected before the cutaneous erythema is marked, and which are accompanied by a redness that gradually fades into the normal hue of the surrounding integument, should serve to differentiate it from erysipelas. A careful consideration of the symptoms and the course pursued, as given under Symptomatology, supplies also most important points for making a diagnosis.

TREATMENT.—Inasmuch as the disease is a streptococcus infection of the lymphatics, the constant presence, in these vessels, of non-irritant germicidal substances is both theoretically indicated and of practical value. The older methods of injecting weak solutions of carbolic acid ahead of the advancing border of the disease, although occasionally productive of most brilliant results, is neither necessary nor to be countenanced when simpler and more efficacious measures are available. Covering the parts with several layers of wet gauze, and generating steam by the rapid passage of an alcohol flame over the gauze will, doubtless, if the process be repeated several times, and especially if it be pushed to the point of vesication, prove successful as a germicide, but it can hardly be recommended for use in this locality. The constant application of an ointment of twenty grains of ichthyol to the ounce of vaseline is the safest and most efficient germicide. Weak bichloride and carbolic-acid solutions have been employed, but are neither so efficient nor so convenient as ichthyol. In broken-down individuals, especially alcoholics, sustaining measures must be adopted, and for the latter class such remedies as will serve to avert delirium tremens. Tonics, sufficient easily digested food, strychnia, alcohol, and other stimulants should be administered when indicated. In drinkers, sleeplessness should be viewed with great distrust, and sleep should be secured by chloral, either alone or in combination with bromides, perhaps by ergot, and at times by the moderately free use of alcohol. The employment of antistreptococcus serum and vaccination on the opsonic theory is on trial as yet. Some authorities claim that the frequent application of alcohol at intervals of an hour or more, with gentle friction toward the focus of the disease, will abort recurrent attacks if the procedure is commenced early.

(See also the general article on "Erysipelas," p. 15 *et seq.*, Vol. III.)

Tuberculosis.—SYMPTOMS AND COMPLICATIONS.—As lupus has already been considered elsewhere *in extenso* (p. 317 *et seq.* of Vol. II.), only a brief consideration will now be accorded it. Lupus of the face shows itself usually in early life as a dull-red spot or small nodule situated on one or both cheeks, on the nose, or in both localities. Sometimes, when the disease is first noticed, only a small area of purplish-red discoloration and thickening of the skin, about a quarter or a third of an inch in diameter, is visible. The larger patches may spread peripherally, or new infiltrated areas may appear. The central portions tend to shrink or, if ulcerated, to cicatrize, producing ectropion of the eyelids or eversion of the lip; or, where deep irregular ulcers form at the angles of the mouth, marked distortion or atresia of this orifice may occur. Extension to the deeper parts is apt to occur. Absorption or destruction of the lupus tissue where the nose is concerned results in shrinking and distortion of the organ, producing a peculiar, sharply pointed tip which has been likened to the beak of a parrot. Where the process is less extensive, the tip of the nose may remain flattened, distorted, congested, and knobbed. The process is essentially a chronic one, and, when progressive, ends in many instances in destruction of the mucous membrane, the septal and alar cartilages, and (usually only to a limited extent) the bones surrounding the nasal orifices. Widespread involvement sometimes occurs in lupus—the cheeks, nose, eyelids, brow, ears, lips, chin, and even portions of the neck becoming markedly thickened, until the palpebral and oral openings become mere irregular, rigid fissures. Sometimes the tissues of the eye itself are attacked, with the result that vision is destroyed. The general health in such cases is apt to suffer, owing to the difficulty experienced in mastication. Similarly, speech and vision may be interfered with from the thickening and rigidity of the eyelids and lips. Œdema, hyperplasia of the skin, abnormal development of the smaller neoplastic blood-vessels, lymphangitis, and pyogenic infections lead to the innumerable forms in which lupus manifests itself; they are accidental, non-essential complications of cutaneous tuberculosis.

Fig. 163.—Lupus of the Lower Part of the Nose and the Upper Lip. (University Hospital, Ann Arbor, Michigan.)

Amelioration or cure of lupus may be brought about, as in other tuberculous lesions: (1) by subcuticular disintegration and reabsorption; (2) by conversion of some of the neoplastic cells into fibroid tissue, or by the penetration of and substitution of the specific granulation tissue by ordinary granulation tissue supplied by the surrounding healthy tissues; and (3) by destructive ulceration, removing all the diseased tissue.

When subepithelial disintegration and absorption of the lupus tissue occur, accompanied as these changes are with repeated exfoliations of the epidermis, there is left a smooth, thin scar covered by a few layers of epithelial cells, and here and there will be seen areas of lupus tissue either unchanged or still ulcerating, or such areas may develop later. While in these central portions a more or less successful attempt at cure is thus initiated, the disease spreads peripherally, or the surrounding tissues become the site of new tuberculous lesions, which, fusing with the primary ones, give rise at times to extensive involvements. When frank ulceration occurs, this may start upon the surface or may result from the spontaneous evacuation of the caseated, liquefied tuberculous foci. The resultant ulcers are shallow, with irregular, fissured, bleeding, unhealthy bases;

Fig. 164.—Lupus of the Nose, Lips, and Cheeks. (University Hospital, Ann Arbor, Michigan.)

the margins are ragged, thin, and sometimes undermined; and foul scabs temporarily cover the lesions, to be separated again and again by the imprisoned discharges. When the lips are attacked they swell enormously; and ulcerated, readily bleeding rhagades form, which scab over temporarily. Extension to the mucous membrane is here the rule, or the primary lesion may be located in the oral cavity. In either case the disease may extend widely, involving the gums, cheek, palate, the pharynx, and even the larynx. If healing eventually takes place, the cicatrices may, in conjunction with the facial scars, seriously interfere with mastication, deglutition, or phonation, or may produce actual aphonia. The mouth becomes distorted, forming a small, irregular, narrow slit, or a "repulsive chasm," the latter state being due to the permanent retraction of the remaining soft parts which are bound down to the bones. Complete closure of the nostrils and almost complete obliteration of the mouth have been observed. Pyogenic organisms having much to do with the destructive ulceration, involvement of the regional lymph nodes is common, while abscess is not unknown. The tuberculous processes originating in the subcutaneous tissues (scrofulodermata) appear as circumscribed nodular masses. They originate in the neighborhood of bone lesions, or in the perilymphatic or lymphatic tissues. These nodules extend peripherally by infiltration of the surrounding parts, undergo caseation and liquefaction in their central portions, and, when the disease process has sufficiently thinned the overlying discolored, purplish skin, this ruptures, giving vent to the cheesy detritus and leaving an ulcer with an unhealthy base and characteristic thinned, ragged, undermined, purplish margins. The fact that a number of lymph nodes are located near the angle of the mouth and over the parotid region determines the location of the ulcers when these lymphatic structures are the starting-points of the scrofulodermata.

(For further information with regard to tuberculous adenitis the reader is referred to the article on this subject, on p. 525 *et seq.* of Vol. II.)

It is important to bear in mind the possibility that lupus may undergo conversion into epithelial carcinoma. This metamorphosis is not restricted to the actively ulcerating portions; in many instances the malignant change commences in the scars. Erysipelas is quite common as a complication, and often is of temporary benefit by hastening the destruction of the lupus tissue.

Diagnosis.—Many cases of extensive so-called "rodent ulcer" (superficial epithelioma) and ordinary epithelioma were in the past, and still are, diagnosed as "lupus exedens." As an aid in distinguishing between these two diseases—lupus or tuberculosis of the skin and epithelioma—it should be remembered that the former usually commences earlier in life and persists to maturity, while epithelioma is very rare in youth and is an acute rather than a chronic process. The history of the course pursued by the disease shows that the ulcerations in lupus are, or have been, multiple, some healing, while the others continue their activity. In carcinoma, on the other hand, the ulcerating lesion is almost invariably single, the margins are hard, infiltrated, everted, and craggy, sometimes presenting a glistening translucent appearance. Furthermore, the base of the ulcer lies deep, is indurated, uneven, and finely granular, and often appears as if varnished by the scanty, sticky, and often offensive discharge. There is no history of its having healed.

The ulcers of lupus are usually superficial, non-indurated,—indeed, they are often soft,—with irregularly disposed heaps of granulations covering their bases, while the edges are often undermined; they never present a reniform or horseshoe-shaped outline. The small, brownish-red nodules of an apple-jelly consistence, so characteristic of lupus, are often recognizable at the periphery of tuberculous lesions.

From the late forms of syphilis lupus is distinguished by the following facts: Acquired syphilis appears usually much later in life; a history of an infecting sore may often be obtained; the ulcers are punched out and they have grayish bases; one may generally find elsewhere on the body other forms of lesions which tend to be, or are, ham- or copper-colored; the apple-jelly nodules are absent; and when crusts are present they are apt to be laminated and of a greenish color, in contrast with the thin crusts seen in lupus. The cicatrices of syphilis, to quote an authority, "are elegant, smooth, delicate, superficial, circular," or they present evidences of one or more rounded destructions of tissue, and "when pigmentation has disappeared they are dead white in color; those of lupus are irregular, are indurated, deforming, yellowish white and reddish yellow." The removal of a small mass of the suspected growth will probably enable the examiner to demonstrate microscopically the presence of tubercle bacilli, or, if an aseptic portion of the tissue be procurable, inoculation of a susceptible animal will soon demonstrate the tuberculous nature of the human lesion. Tuberculin injections, the ophthalmo-reaction, or the von Pirquet cutaneous modification, may sometimes settle the diagnosis. (For the differential diagnosis from rhinoscleroma and from rhino-pharyngitis mutilans see p. 824 of the present volume and p. 67 of Vol. II.)

Prognosis.—The prognosis is uncertain and variable, but on the whole favorable, because of the paucity of tubercle bacilli in the skin lesions. Even in the most severe cases of facial lupus recovery often occurs with an astonishingly small amount of deformity. The scrofulodermata are also capable of marked improvement or cure by perseverance with appropriate treatment. On the other hand, fatal systemic involvement may result promptly from a small tuberculous lesion, or this accident may not occur for years, if ever, even when the local tuberculosis is most extensive.

Treatment.—The constitutional measures are those proper for tuberculous disease in other parts of the body; change of climate and an open-air life seeming to be of decided benefit. (The reader is referred to page 592 *et seq.* of Vol. III. for information with regard to the employment of tuberculin.) The local treatment of the disease is confined to removal by physical means (the actual, potential, or galvano-cautery) and the employment of phototherapy. The latter does not tend to diffuse the bacilli either locally or throughout the body (a proved possibility), but it consumes much time. The various methods of curettage, the proper caustics to select, when to use the knife, and what are the best local applications to make are matters that have already been considered in the article on Surgery of Diseases of the Skin (p. 303 *et seq.* of Vol. II.).

Free incision of circumscribed areas, followed by skin grafting (either the Thiersch or the Wolfe method), is sometimes a good practice. It may be employed either as an independent plan of treatment or as a measure supplementary to some of the others already mentioned. Later, when a sufficient length of time has elapsed, after full cicatrization, to render it reasonably certain that a cure has been effected, various plastic procedures often become necessary to relieve the ectropion, to open the closed nostrils, to enlarge the mouth or render possible its closure, etc.

Syphilis.—As the article on syphilis in Vol. II. (page 91 *et seq.*) partakes rather of the nature of a general survey, leaving to the special regional articles the task of furnishing further details concerning the manifestations of the disease in various parts of the body, it is proper for us to consider here briefly both the primary and the later lesions of syphilis as they are observed upon the face.

Symptoms.—While a chancre in the region of the face is usually located upon the lips, it may also occur on the chin (Fig. 165), the nose, or the cheek. Its development in one of these unusual localities may be the result of unnatural intercourse, or a razor cut or some other accidental wound may become inoculated secondarily. Abrasions or fissures of the lip can readily be inoculated from cigars or from pipe-stems that have been used by those who have mucous patches or other syphilitic lesions of the mouth and throat. Kissing is sometimes a means of accidental inoculation, and so also is drinking from public drinking-cups or from a vessel which had been previously used by a person affected with oral syphilis.

Fig. 165.—Chancre of the Chin near the Angle of the Mouth. The lesion is no longer at its full stage of activity. ("Cliniques Médicales Iconographiques," par Messieurs Haushalter, Étienne, Spillmann, et Thiry, Paris, 1901.)

As to the nature and behavior of the local lesion itself it is sufficient to say that, about ten days or two weeks after a suspicious exposure or an accidental slight traumatism, there appears a small ulcer, the margins and base of which—the latter covered with a scanty secretion—are densely infiltrated. This ulcer increases rather rapidly in size, attaining in some instances that of a silver ten-cent piece; and if at the same time it is found that the submental and submaxillary lymph nodes are enlarged, hard and movable, but not tender, we may feel almost certain that the lesion is a chancre and not a carcinoma. A short delay, however, will settle the diagnosis, for, if the ulcer is a chancre, skin and throat eruptions will soon be seen, and both the primary and the secondary lesions will rapidly disappear under antisyphilitic treatment.

Late secondary syphilides, both the pustular and the tubercular forms, when grouped together at the common sites of lupus, such as the lip, nose, cheek, or forehead, may lead to seriously distorting scars strongly suggestive of those caused by lupus. A still closer resemblance is presented by small cutaneous gummatous infiltrations and their results. The greater depth of the ulcers of syphilis; the rapidity with which they extend, producing in a few weeks results that require months or years in lupus; the absence of recurrent nodules in syphilitic scars; the reniform, scalloped, horseshoe-shaped serpiginous destruction of the tissue, and the similarly shaped scars which as a rule follow syphilitic ulcerations—all these are distinguishing features that merit consideration. When syphilis is of hereditary origin, the presence of saddle-nose, the condition of the teeth, etc., all aid in the differentiation. The tuberculin test may also prove of service.

Prognosis.—The prognosis is the same here as it is when a lesion of the same nature and the same stage of the disease is located elsewhere in the body.

Treatment.—Protection of the sore and non-irritating applications alone should be employed until it is positively ascertained that the lesion is of a syphilitic nature. Then the appropriate constitutional treatment should be instituted. (See Vol. II., p. 132 *et seq.*)

Saddle-Nose.—Saddle-nose consists in a depression of the bridge of the nose, the result of severe fracture or of syphilitic disease, which latter may have been purely intranasal or have also involved the cutaneous surface, destruction of the bones and cartilages resulting from ulceration and osseous necrosis following gummatous infiltration.

Treatment.—Permanent cicatrization of the diseased area by constitutional and local treatment must first be assured. One of three general methods can then be adopted, viz.: (1) after proper loosening of the retracted tissues by subcutaneous or submucous dissection, a permanent gold, platinum, or celluloid bridge may be introduced; (2) if the nasal passages are unobstructed the soft parts may often be satisfactorily raised by paraffin injections; (3) after open dissection and elevation of the depressed parts, osteoplastic or cutaneous flaps can be employed to reconstruct the nose. (For details and indications for each class of operations see the article on Plastic Surgery in Vol. IV.).

Actinomycosis.—Langenbeck, in 1845, noticed sulphur-like granules in the pus of an abscess of the jaw. Bollinger, in 1877, demonstrated that a ray fungus was the cause of "lumpy jaw" in cattle. Israel, of Berlin, in 1878, proved that the same was true for man. Only two of the numerous ray fungi have yet been proved to be pathogenic, viz., that one which causes ordinary human actinomycosis and the (possibly) altered form which is productive of "Madura foot."

Etiology.—Wright has apparently demonstrated that some of the suppurative lesions that are occasionally confounded with actinomycosis result from infection by organisms which are termed by various writers streptothrix, cladothrix, oöspora, but which, as he contends, should be grouped under the title

"Nocardia." None of this group produces the characteristic granules or "Druesen." The term "actinomycosis" should therefore be applied only to the disease which is produced by the Actinomyces bovis—a disease in which there develops a suppurative process associated with the formation of granulation tissue, the pus containing the characteristic sulphur or fish-roe bodies (dense aggregations of branched filamentous micro-organisms) mingled with transformation and degeneration products. The organism does not flourish in ordinary culture media and does not develop at ordinary room temperatures; it grows best at 37° C. (98.6° F.). There are grounds, therefore, for believing that the organism normally develops in the buccal cavity and the gastro-intestinal tract of man and animals. The accepted view as to its introduction from without by infected spears of grass, straw, etc., is doubtful, the frequent association of these with actinomycosis being equally well explained by considering them as agents providing a means of entrance for germs already present, and as preparing the soil by lowering the normal resistance of the tissues.

The actinomyces commonly obtain entrance by some lesion of the epithelium of the oro-pharynx, the respiratory or the alimentary tract, or the skin, although a carious tooth has been claimed to have been the infection atrium. A local lesion at the site of entrance is rare, but the disease has been observed near the orifice of a dental fistula which originated, as was claimed, from an acute alveolar abscess, but this was possibly an acute suppuration occurring in a primary actinomycotic focus at the root of a carious tooth. The effect of the fungus upon the tissues is to excite the production of granulation tissue, a true granuloma being formed, which later breaks down with suppuration. The production of pus is probably due to secondary pyogenic infection, the actinomyces being believed by many to be non-pyogenic. (Wright, it should be stated, holds the opposite opinion.*)

The organisms exist in larger numbers in the discharges than in the granulation tissue, or at least they are more readily detected in the pus, which is said at times to give off a distinctly earthy odor. The fungus may be seen in the form of granules, visible to the naked eye, or only as microscopic threads, dividing at acute angles, sometimes only distinguishable with great difficulty after staining with gentian violet. As Bevan points out, the gritty bodies, of a sulphur-yellow color, are not so common as the minute gray or translucent granules that somewhat resemble fish-roe; indeed, in nearly all the cases studied in this country, the calcareous and sulphur-yellow bodies have been absent. Although the usual starting-point of actinomycosis is the mouth, especially near to or involving the orifice of Stenson's duct, inoculation from without by the penetration of infected foreign bodies has been reported. When

* "The Biology of the Micro-organism of Actinomycosis" by James Homer Wright, M.D. The Journal of Medical Research, New Series, vol. viii., May, 1905. This is a classical paper with an elaborate and complete bibliography.

lesions of the mucous membrane result they consist of small, painless, slowly enlarging granulomatous tumors, which gradually infiltrate all the tissues of the cheek until finally the skin is attacked. Owing to the slow development of the granulomata the hyperæmia is steadily maintained, and this in turn stimulates the proliferation of the tissue elements, which ultimately become organized, producing the characteristic "board-like" induration. For anatomical reasons the infiltration usually reaches the skin of the cheek at a point anterior to the masseter, the tumor in its earlier stages being dense and nodular when palpated. Dense bands of infiltrated tissue are frequently felt in or beneath the mucous membrane. According to Lexer they extend from some part of the upper or

Fig. 166.—Early Stage of Actinomycosis. Peridental infection atrium; abscesses opening in mouth below zygoma, and later over the angle of the jaw and in the temporal region. (University Hospital, Ann Arbor, Michigan.)

lower jaw to the tumor, thus affording evidence of the course pursued by the fungus through the tissues. These bands represent inflammatory exudate that has in part been absorbed and in part has become organized.

Symptoms.—A hard, nodular induration makes its appearance in one cheek, steadily increases in size, and finally reaches the integument in front of the masseter. (Fig. 166.) The skin in this region is of a dull reddish hue, and it finally gives way at one or more places corresponding to the more prominent portions of the tumor, which as a whole is of an ovoidal form. The infiltration of the buccal tissues accounts for the difficulty in opening the mouth, and this early trismus is increased when, as is often the case, the masseter, the temporal, and the pterygoid muscles become infiltrated. From the region of the cheek the disease may spread with destructive effect to the base of the skull, and this is particularly apt to happen when the infection atrium is in the upper jaw. A more superficial involvement of the temporal region may occur by extension from a buccal focus, and when this occurs one-half of the face and the temple become converted into a board-like, indistinctly outlined swelling which later softens and breaks down at several points, leaving suppurating ulcers accompanied by sinuses that lead in various directions. (Fig. 167.)

In the earlier stages, before secondary infection has occurred, the disease runs an afebrile course.

Fig. 167.—The Same Case as that Shown in Fig. 166; Later Stage of the Disease. (University Hospital, Ann Arbor, Michigan.)

Secondary infection with pyogenic and saprophytic organisms may greatly alter the characteristic appearances by leading to deep-seated, malodorous, acute abscesses with marked constitutional symptoms and great destruction of tissue. Genuine erysipelas is not an uncommon complication. Fever is of course present with these infective lesions, and usually the more or less calcified actinomycotic granules can be seen and felt in the discharge.

Diagnosis.—As features that are very suggestive of actinomycosis may be mentioned the following: A poorly defined, rather dense infiltration which pursues a chronic course; a denseness which at first is observable in every part of the swelling, but later gives place at various points to a soft condition due to the breaking down of the tissues; and the absence of fever and pain, at least until secondary infections supervene. If, in addition, it is found that there are indurated bands lying beneath and in the mucous membrane and extending from it to one or other jaw, the presence of an actinomycotic process may be assumed with considerable assurance. The detection of the granules which, with or without staining, show microscopically the characteristic fungi, their degenerated clubs, or the characteristic mycelial threads, settles the question.

Owing to the sites of the deeper infiltrations it is an easy matter to mistake the disease for an osteomyelitis, a sarcoma, or a gumma of the jaw, but in most cases such an error is soon corrected by the appearance of the characteristic ulceration and granules. E. Lexer describes as frequent a small and rather circumscribed variety of the actinomycotic lesion, which lacks the characteristic indurated base and margins and breaks down into a simple abscess. He says that the inexperienced may readily mistake this for an inflamed sebaceous cyst. All doubts, however, should be promptly solved by an examination of the discharge microscopically or by culture methods. The microscopic examination, it is important to remember, should include staining and a search for the atypical forms as well as for the typical specimens pictured in the books; and it may also be found necessary to make repeated examinations. When, for any reason, a microscopical examination cannot be made, the finding of an indurated strand that leads to the jaw should be considered valuable corroborative evidence.

Prognosis.—Of late years the prognosis is regarded as more favorable than it was formerly believed to be, and this is especially true of those cases in which the disease is confined mainly to the exterior of the cheek. Even when the tissues on the inner side of the lower jaw are also involved, proper treatment often ends in a cure, provided the case be seen before the disease has advanced too far. It has also been found possible to prevent the disease from reaching the base of the skull or the vertebræ, by way of the upper jaw, in cases in which the pterygoid muscles were involved. The so-called pyæmic form—by which expression is meant the embolic dissemination of the actinomyces—is of course practically hopeless. It seems almost unnecessary to add that a genuine pyæmia, such as may occur in the course of any pyogenic process, can equally well develop in the later stages of this disease.

Treatment.—The older methods, that involved partial or complete excision of portions of the bony framework of the face, have been almost entirely superseded by the practice of freely opening all abscesses, curetting away all granulomatous tissue, applying freely iodine or silver nitrate to destroy any remaining organisms, packing the wound with iodoform gauze, and administering internally drugs that are destructive to the actinomyces. If sinuses persist despite these measures, the latter should be repeated, and in addition it will perhaps be well actually to excise—if this be found practicable—all operable sinuses. Ten grains of potassium iodide should be administered three times daily, the dose being rapidly increased, in the course of about ten days, to 180 grains daily.* This internal treatment should then be intermitted for a week, and again resumed. The employment of the x-ray is of distinct advantage; it probably acts by setting free nascent iodine in the diseased tissues.

The potassium-iodide method of treatment is probably superior to that by kataphoresis, formerly advocated in the treatment of actinomycosis.

Bevan, of Chicago, has recently shown that copper sulphate has an equal, if not superior, power of destroying the ray fungus in the tissues. Commencing with one-fourth of a grain of the salt he gradually increases the dose until one grain three times daily has been reached. The possible advantages of a combined copper and iodine treatment has also been suggested by this author. If throat lesions exist, iodine gargles may be employed as succedanea.

Cicatrices.—Those which present a nodular, stellate, or bridle-like form, productive of much deformity, usually result from the prolonged cicatrization incident to extensive losses of substance. Sometimes these elevated scars have already attained considerable prominence at the time when final healing occurs or shortly after cicatrization, but this is not invariably the case; for, long subsequently to the healing, non-elevated scars may take on this hypertrophic process, resulting in the formation of tumors that present the most varied appearances. Even short linear scars may thus undergo hypertrophy. While it differs from keloid in the more irregular distribution of the bundles of fibrous tissue and in the entire absence of the papillary layer of the skin, this condition is closely allied to keloid. Like non-hypertrophied scars, those under consideration gradually become less vascular as the neoplastic fibrous tissue contracts.

Treatment.—Where ectropion of the eyelid or some deformity of the mouth results, excision, followed by a plastic operation or skin grafting or both, is indicated; but, where merely a cosmetic effect is aimed at, very careful judgment should be exercised in the selection of cases, lest the operation scar be as conspicuous as, or more conspicuous than, the original cicatrix. Again, the condition may be in reality not a simple scar, but a commencing keloid; in which event matters will, as a rule, only be made worse by the knife. A careful use of phototherapy or of the x-ray offers sufficient prospect of betterment to warrant a trial of these agents. Thyroid extract has been deemed useful in certain reported cases.

Keloid.—Etiology.—A keloid is a connective-tissue neoplasm, consisting of dense fibrous tissue that involves the corium and extends especially along the adventitia of the blood-vessels. Growths of this nature follow traumata

* The author, in one case, gave the patient—at the end of eight days and in the course of twenty-four hours—three hundred and fifty grains of potassium iodide without any evil effects.

which involve at least the papillary layer of the skin. There exists in the negro race a distinct predisposition to the development of keloid.

Symptoms.—When the disease develops independently—*i.e.*, when it does not attack a pre-existing scar—there appears a small elevated nodule which slowly enlarges and at the same time shows a tendency to assume an elongated oval form, with irregularly radiating, well-defined projections that give to the tumor a rude resemblance to a crab. In a certain number of cases the linear form is maintained. Generally devoid of hair, the growth is a smooth, firm, elastic, pale red, elevated, cicatrix-like mass. Usually it is painless, but sometimes pressure reveals the fact that the part is quite tender. Still more rarely itching is complained of. When inflamed, a keloid temporarily suggests the possibility of malignancy, but the inflammation usually subsides spontaneously. The tumor may develop rapidly or slowly, but after it reaches a certain stage of development it is apt to remain stationary for a time. Afterward it may again increase in size, or else it remains stationary during the remainder of the patient's life. In very rare instances the tumor disappears spontaneously.

Prognosis.—The prognosis is not favorable, although a spontaneous cure may result or treatment may prove to be effective.

Diagnosis.—The diagnosis is easy; the only condition with which it can be confounded is a simple cicatrix, which differs in color, in outline, and usually in elevation, as well as in consistence; moreover, even hypertrophied scars, after they have once formed, do not increase in size.

Treatment.—Removal is at best a doubtful expedient and should never be attempted as long as the growth is enlarging. Repeated scarifications or multiple electrolytic needle punctures may succeed. Thyroid extract seems to have proved beneficial in a few instances, while phototherapy and the *x*-ray have been successful in a fair proportion of cases. These last two agents should be given a trial in combination with the exhibition of thyroid extract, before even electrolytic puncture or scarification is resorted to. Static electricity, employed in the form of sparks, each séance being limited to eight or ten minutes for the larger growths and to five or six minutes for the smaller ones, has been highly vaunted. Recent keloids or recurrences after operation yield most readily to this treatment, but care should be exercised not to produce vesication by the undue length of the applications.

Glanders.—Etiology.—Glanders results from the implantation and multiplication, in the tissues, of the Bacillus mallei. The fact that, in an overwhelming majority of cases of glanders, the disease manifests itself primarily in the nasal mucous membrane overshadows the equally indubitable fact that the infection atrium may be located upon the skin of the face from inoculation of some open skin lesion.

The usual manifestations of glanders have already been discussed in another part of this work (Vol. II., p. 41 *et seq.*), and we are concerned in the present article only with the possible occurrence of the disease upon the skin of the face in the absence of most of the distinctive peculiarities displayed by glanders in its ordinary forms.

Symptoms.—Fever and malaise precede by some days any local manifestation. The point of inoculation shows evidences of a distinct phlegmonous inflammation resulting in the formation of a nodule or nodules. Vesicles form over the diseased area, early inflammation of the lymph vessels and nodes sets in, and possibly there is also phlebitis. Suppuration promptly follows the vesication, and one or several phagedenic ulcers result. There are also, in most cases, marked œdema and widespread infiltration which give to the skin a peculiar shiny, dusky-red appearance. The ulcers which result from the breaking down of the nodules have prominent margins with somewhat undermined, irregular edges; they are associated with widespread destruction of the tissues. When the lymph nodes are early involved, similar conditions develop in them. Sooner or later the bacilli become more or less generalized, and then secondary nodules form in the nasal chambers, exciting first a thin, then a gluey, and finally a muco-purulent, often bloody and offensive nasal discharge. More rarely the disease remains practically local, and in these exceptional cases it is most difficult to distinguish the chronic ulcers that characterize the disease from those belonging to actinomycosis, to tuberculosis, or to syphilis in certain of its stages.

Prognosis.—The acute form of facial glanders, in which other parts speedily become infected, nearly always proves fatal. In the subacute or chronic varieties a fair number recover after more or less mutilation.

Diagnosis.—The diagnosis must depend in some degree upon the history of possible exposure to infected animals; and, in addition, there are the following facts that help to distinguish the disease; the formation of one or several nodules that rapidly disintegrate; the presence of peculiar cord-like lymph vessels in connection with these nodules; the development of secondary nodules in the nasal cavities in the more chronic cases, the tumors pursuing the same course as the primary one; and the existence of widespread phlegmonous processes around primary insignificant nodules. A confirmation or a disproval of the diagnosis, however, necessitates a bacteriological examination and inoculations of susceptible animals.

Treatment.—The primary nodule and all accessible secondary ones must be destroyed by extensive excision or by the use of the actual cautery, these measures being perhaps supplemented by the free use of zinc chloride (one part in eight parts of water). Sometimes free curettage, followed by the use of the actual cautery or the application of the zinc solution, is the better practice. In all other respects the surgeon must be guided by the general principles applicable to the treatment of any septic or infective process that is accompanied by a free discharge from the wound.

TUMORS OF THE FACE.

A. Benign Tumors.

Lipomata.—Etiology.—In the face, as in other portions of the body, adipose tissue, being only areolar tissue the cells of which have been infiltrated with oily materials, is apt, when a local hyperæmia is long maintained, to undergo an overgrowth. Facial lipomata may grow to a considerable size. It would naturally be expected that fatty tumors would most frequently develop in those regions of the face where adipose tissue is most abundant, and such is indeed the fact. The most common site is the adipose cushion situated below the malar bone and overlying the buccinator. The localities where these tumors rarely appear are the region of the chin, over the mandibular attachment of the masseter, the eyelids, and the dorsum of the nose. Fatty tumors of the lips are sometimes located just beneath the skin, and sometimes they seem to be lodged in the intermuscular areolar tissue or in that which surrounds the lymph nodes. In either of the last two positions the tumors, being nearer the buccal than the cutaneous surface, may eventually present themselves beneath the mucous membrane rather than beneath the skin. Outlying portions of diffuse lipomata of the neck sometimes encroach upon the adjacent regions of the face. Congenital lipomata have been reported.

The foregoing remarks apply chiefly to pure lipomata, but some growths are really fibrous or angiomatous, portions only of their connective tissues being fattily infiltrated, *i.e.*, lipomatous.

R. Cecca* maintains that fatty overgrowths and so-called tumors of the buccal adipose tissue (often classed as adiposis, lipomatosis, true lipoma) are all in reality due to inflammation of the adipose layer secondary to an inflammation of some neighboring tissue, and should be termed inflammatory lipomatosis; and as an example he cites a case of his own which followed periostitis of the upper jaw. Whether this be the correct pathology of lipomata of the cheek or not is something which cannot be positively affirmed, but it is probably correct in the main.

Symptoms.—The characteristics of a lipoma of the face are these: A soft, elastic, usually coarsely lobulated, fairly well defined, and certainly non-infiltrating tumor makes its appearance, grows slowly, and is not at all painful; the overlying skin or mucous membrane is unaltered, except that it is perhaps somewhat thinned and sometimes contains enlarged vessels; in some instances, owing to the predominance of fibrous tissue, rather hard, irregular masses may be found in the tumor; and both in this and in the angiomatous forms the

* La Riforma medica, December 22d, 1906.

sharp delimitation of the pure lipoma is lacking, owing to the absence, in whole or at certain points, of a capsule.

Diagnosis.—The characteristics just mentioned and the absence of those features and symptoms which are distinctive of chronic abscess, of dermoid, sebaceous, or mucous cysts, of lymphangiomata, etc., afford data sufficient for making a diagnosis.

Prognosis.—If the tumor is completely removed, a recurrence will not take place.

Treatment.—Active intervention is demanded only when the growth becomes a source of annoyance, as when a mass lying beneath the mucous membrane is frequently caught between the teeth, when one in the parotid region is believed to be a tumor of that gland, or when through error a diagnosis of abscess, dermoid, or even a malignant growth is made. It is scarcely necessary to add that, for cosmetic reasons, the patient often asks to have the tumor removed. Submucous growths can usually he shelled out from the buccal side, care being taken to avoid damaging Stenson's duct. In the case of a subcutaneous growth, on the other hand, some of the important branches of the facial nerve are imperilled by operative interference. Proper incisions, piecemeal removal, and avoidance of all unnecessary use of the knife should prevent these untoward accidents.

Connective-Tissue Tumors.—Under this general head are included the following subvarieties: fibroma, pigmented nævi, fibroma molluscum, and plexiform or cirsoid neuromata. The sarcomata, although some of the forms of these new growths are relatively benign in character, will receive consideration in the section on Malignant Tumors.

Fibromata.—Pigmented nævi, often more or less covered with scattered hairs (nævus pilosus or hairy mole, Fig. 170), are variously classed among the fibromata and lymph-angiomata. Ziegler, for example, holds the latter opinion, while some of the German surgeons insist that these nævi are really fibromata of nerves, due to proliferation of the connective tissue of the endoneurium, possibly of the perineurium—in other words, that they represent a fibromatosis of the nerves and are of congenital origin. The discolored integument may vary in tint from light chocolate to an almost pure black. The skin is usually normal, but the epidermis may be hypertrophied and also discolored (nævus verrucosus). (Figs. 168 and 169.) Usually occupying but a limited area, they may cover large portions of the face, and at the same time numerous small tumors of a similar nature may be distributed over other portions of the body. (See farther on.) They usually appear as ovoidal, rounded, possibly irregularly outlined tumors, but slightly elevated above the normal skin level. When they form slightly projecting, soft or moderately firm tumors, the term "nævus molluscifomis seu lipomatodes" is sometimes applied to them, and when pigmentation is slight or entirely absent the name "white mole" is often employed.

Treatment.—According to W. A. Pusey,* pigmented nævi and flat vascular nævi can be most successfully treated, with the minimum of scarring, by the use of carbon-dioxide snow. As the liquefied gas escapes from an ordinary metal cylinder, such as is used in charging soda-water fountains, the snow is collected in a piece of chamois leather; the cylinder is best tipped so that the opening is dependent. The snow is moulded between the layers of chamois skin by the fingers and trimmed with a knife to the shape of the lesion, or into cubes measuring about 1 cm. (⅜ in.) each way. Grasped in forceps the mass is pressed against the lesion, it being remembered that the greater the pressure the more deeply are the tissues frozen. Where a large area is to be dealt with, the cubes are used in such a manner that no overlapping with a second freezing is likely to occur. From ten to thirty seconds, Pusey says, gives the best results with the least scarring. A second treatment is better than a too deep primary freezing, especially in vascular nævi, as in the latter case the scar is likely to be too white. The immediate effects vary from a wheal up to a superficial crust. In the case of the wheal, an exposure of five seconds' duration is sufficient to produce the lesion, which then in the course of about five days passes through the different stages of vesication, inflammation, and crusting over. No scarring follows. After a freezing of thirty seconds' duration the superficial crust formed does not drop off until after the lapse of about two weeks, and there will remain a certain amount of permanent scarring. A freezing of fifty seconds will produce an eschar which separates, without suppuration, only after the lapse of several weeks, leaving a superficial white scar. A freezing of from five to ten seconds serves to remove "thin layers of pigment from the skin." If a second application seems desirable it should not be made until all effects of the previous freezing have disappeared.

Fibroma Molluscum.—In this form of disease distinctly circumscribed nodules are felt, at the very outset, in or beneath a normal, possibly pigmented skin. In a few cases, however, the skin is not normal, but presents enlarged vessels, sometimes scattered comedones, or dilated sebaceous-gland ducts. These small growths are painless unless they become inflamed as a result of accidental traumatism. When they are of considerable size, or when several are located close together, the growths become pendulous, and then, in conjunction with other processes presently to be described, dermatolysis may occur. The number of these growths varies from three or four to thousands, and they may be located on almost every portion of the body besides the face. Individually they form moderately firm, elastic, sometimes slightly lobulated masses, or they may feel like a double fold of skin containing a "cord-like" body. Hyde maintains, as a characteristic sign which may often be made out, that firm pressure over the small masses gives the impression of a thinned corium through which the tumor

* "The Use of Carbon Dioxide Snow in the Treatment of Nævi and other Lesions of the Skin." W. A. Pusey, Journ. Am. Med. Assoc., vol. xlix., p. 1354.

can be forced; in other words, the sensation is as if there were a hole through the true skin. Soon the overlying integument becomes adherent to the growth, which then, in its subsequent history, may follow one of two courses: It may either disappear entirely during the third decade of life, or, after it has attained its full growth, it may undergo gradual involution, as manifested by such changes as the shrinking of the skin attached to the summit of the mass, the occurrence of pedunculation, the closing of the hole in the skin referred to above, the formation of wrinkled pouches in the integument, etc.; as the result of which changes there remain ultimately multiple warty or nipple-like elevations of tissue. (Hyde.) The period required for the full evolution of these tumors may be only four or five months or it may amount to as much as one year, development and retrocession being of about equal duration. The development of flaps in consequence of the traction exerted by numerous closely related tumors or by a single larger one, combined with the atrophy which the masses themselves undergo, leads to more or less extensive dermatolysis, with the formation of multiple permanent skin flaps, which are most disfiguring when they occupy the face, and which may cover an eye (supraorbital and palpebral regions) so completely as to obscure its vision. Such cases supply the originals of the unpleasing illustrations of fibroma molluscum found in most dermatological treatises.

Plexiform or Cirsoid Neuroma.—The plexiform or cirsoid neuroma consists of convoluted, twisted masses of thickened, nodular nerves; the pathological changes involving all the smaller branches of a given nerve or only those of its main divisions. The growth of fibrous tissue arises chiefly from the endoneurium, and as a result the nerve filaments increase both in number and in length. (Ziegler.) Both sensory and motor nerves may be attacked. Occasionally, sarcomatous degeneration attacks plexiform neuromata as well as other forms of neuro-fibromata, and all varieties of neuro-fibromata are very prone to undergo myxomatous changes. Plexiform neuro-fibromata not uncommonly start from the deeper portion of a pigmented nævus. In some of the older growths the nerve elements become so completely atrophied that it is difficult to identify them, the tumor then seeming to be composed solely of connective tissue.

Diagnosis.—On palpation a cirsoid neuroma conveys to the finger the sensation of thickened, tortuous, and nodular cords—a sensation not unlike that, as Park has pointed out, conveyed by a varicocele. This tumor is unlikely to be confounded with anything but a lymphangioma or a hæmangioma. The former is covered with unaltered or thinned skin which is closely applied to the soft convoluted or cystic masses of which the tumor is formed, and pressure will markedly diminish its bulk. The skin covering a hæmangioma almost always contains enlarged vessels or shows the tint of the blood in subjacent vessels. The soft, compressible contents more or less tensely fill out the covering skin, while straining, stooping, or coughing will increase the bulk of the tumor. (Farther on in this article, under the head of Angioma, the reader will find additional details on this subject.)

Treatment.—When anatomically possible the preceding varieties of connective-tissue tumors should be excised.

New Growths Composed of Blood-Vessels; Hæmangiomata.—Under this heading the conditions known as telangiectasis (nævus araneus, spider cancer), nævus flammeus, cavernous angiomata, and cirsoid aneurisms will receive brief consideration.

Telangiectasis; Nævus Araneus; Spider Cancer.—The etiology of these pathological conditions is uncertain. While they are regarded by some as only of congenital origin, it is an undoubted fact that many develop in adult life, either as single or as multiple diffused or localized new growths. It is therefore probable that there is one form that arises from congenital excess of vascular development and another of distinctly post-natal origin, consisting of acquired dilatations combined with newly formed capillaries. The diffuse form is very rare.

Although all forms of vascular tumors have been observed occasionally to undergo retrogression or an actual spontaneous cure without treatment, this occurrence is most unlikely. An increase in size is what may be expected in the majority of cases.

In its general appearance the circumscribed form is characterized by flattened, slightly elevated areas of enlarged, racemose, plexiform minute blood-vessels situated in the skin, which is either pinkish or purplish in hue.

Nævus Flammeus; Nævus Sanguineus.—These growths are of congenital origin and are usually visible at birth, but if they are not then visible they always develop within a short time subsequently to delivery. They consist chiefly of enlarged cutaneous capillaries, but the small veins and the arterioles may participate; indeed, the vascular changes may affect primarily, and very often secondarily, the subcutaneous tissues. When they are confined strictly to the integument, the affected area is slightly elevated and varies in hue from a bright red to a dark purple. The growth may be single and not larger than the head of a pin, and the subsequent enlargement may simply keep pace with the growth of the individual; or it may primarily involve one-half of the face, or an equally extensive involvement may result from the rapid increase of a small tumor. These growths are irregular in outline, but are usually distinctly circumscribed. While as a rule they are smooth on the surface, they may become tuberous and nodular; they may feel almost spongy; or they may be so firm as to resist all ordinary attempts to compress them. If the new growth of blood-vessels extends deeply into the tissues, it will be found impossible to obliterate the color of the patch by pressure.

The particular shade of color of these port-wine or strawberry "mother's marks" and nævi depends upon the predominance of one or other of the three classes of blood-vessels—the arterioles, the venules, or the capillaries; and in accordance with such predominance the growths or marks are often termed capillary, arterial, or venous angiomata. (Figs. 168 and 169.) In the softer varieties stooping, straining, or coughing causes the growths to swell up and increase in depth of color, while firm pressure will render them small and of a lighter tint. These vascular nævi may form a part of the tissues of a mole or lymphangioma.

PROGNOSIS.—So far as this is concerned it may be stated that in the majority of instances the nævus grows until it reaches a certain size, after which it remains stationary for life, or undergoes secondary changes with obliteration of the component vessels and shrinking of the tumor into a scar-like mass, covered possibly with pigmented skin.

FIG. 168. FIG. 169.

FIGS. 168 and 169.—Front and Side Views of the Face of a Young Woman Affected with Extensive Pigmented Nævus Verrucosus. ("Cliniques Médicales Iconographiques," par Messieurs Haushalter, Étienne, Spillmann, et Thiry, Paris, 1901.)

There are some cases, however, in which the disease gradually involves the environing tissues, until there is finally produced an enormous irregular tumor which is raised well above the level of the skin of the cheek and causes bulging of the mucous membrane inward. Trauma or some unknown cause leading to thrombosis may, in very young infants, produce inflammatory changes which result in gangrene, the "line of demarcation of the destructive process being exactly limited to the border of the angiomatous tissue." (Hyde.) The resulting scar is usually insignificant. Hemorrhage, although greatly dreaded by the laity, is neither common nor difficult to arrest.

Cavernous Angiomata.—This form of vascular new-growth, which is rarely congenital but usually appears soon after birth, may also result from changes that take place in a nævus or even in a superficial telangiectasis. Cavernous growths consist of intercommunicating loculi lined with endothelium, and the blood with which they are filled is supplied by neighboring vessels, which are usually enlarged. The partitions between the blood spaces are formed of more or less firm connective or fibrous tissue. These growths, when situated in the face, are said to be met with much more frequently in females than in males. Many cavernous angiomata, when they are fully formed, are more or less completely encapsulated. (See Fig. 171.)

Fig. 170.—A Hairy Mole (Pigmented Nævus) of Cheek. (After Tillmanns.)

Although traumatism or inflammation may lead to thrombosis and a partial or complete cure, this is a very rare event. The usual outcome is that the growth either increases continually or, after reaching a certain size, remains quiescent.

A cavernous angioma presents the appearance of an ill-defined, spongy mass covered by discolored skin containing enlarged vessels, and with the purplish hue of venous blood often indistinctly showing through the thinner portions of the overlying integument. Under pressure the enlarged vessels disappear, but they immediately reappear when the pressure is withdrawn. In addition, unless the tumor is very small, enlarged, tortuous, visibly pulsating arteries can usually be detected leading up to and becoming lost in the mass. Auscultation often detects a distinct murmur.

Fig. 171.—Angioma Cavernosum of the Right Cheek and Lower Lip in a Girl Fourteen Years Old. (D. G. Zezas, of Lausanne, Switzerland, in *Deutsche Zeitschrift für Chirurgie*, April, 1906.)

It is important to bear in mind the possibility that what seems to be a simple angioma at the root of the nose may prove in reality to be an encephalocele. (In regard to this point consult the article on Surgical Affections and Wounds of the Head, in the present volume.)

Treatment.—Destruction, removal, and the induction of thrombosis comprise the fundamental measures which may be employed in the treatment of these tumors. Telangiectasis and the smaller superficial nævi can be dealt with best by careful electrolysis, although thermo-puncture may also be employed to advantage. For the larger growths subcutaneous or percutaneous strangulation by ligature, or complete removal by dissection after reflecting proper skin flaps, is the best practice. When it is possible, carrying the knife wide of the tumor, so that the supplying vessels may be early secured, renders such operations feasible; for the bleeding from the innumerable vessels of the angiomatous mass when it is not prevented in some such manner, is very copious and extremely difficult to control. Some surgeons, however, prefer to do this work as a separate prelimi-

FIG. 172.—Cirsoid Aneurism Involving all the Tissues of the Cheek. (University Hospital, Ann Arbor, Michigan.)

nary operation, on which occasion they secure all the arterial feeders of the tumor which can be made out, by subcutaneous ligation or by open incisions. When cavernous angiomata are well encapsulated, their removal is comparatively easy and safe, provided the capsule is not encroached upon.

Arterial Varix or Cirsoid Aneurism.—This form of angioma, consisting of elongated, tortuous varicose arteries, is not uncommon on the face and scalp. It may be of congenital origin, but when developing independently of manifest prior vascular changes it has seemed to be caused by some kind of traumatism, more particularly by a contusion.

A cirsoid aneurism presents the following characteristics: It is a soft, irregular tumor, manifestly composed of a congeries of enlarged, convoluted, tortuous, varicose, visibly pulsating vessels, and yet as a whole it does not communicate to the hand of the examiner a true expansile aneurismal impulse. When a murmur is audible, as it sometimes is, it will be observed that this murmur differs materially from that heard over a true aneurism. (Figs. 172 and 173.)

PROGNOSIS.—This is most uncertain except when total excision is possible.

TREATMENT.—Among the different methods of treatment which have been tried with varying degrees of success the following deserve to be mentioned: the injection of coagulating fluids into the tumor; ligation of the vessels which supply it; the employment of the thermo-cautery and of various electrical procedures. The injection of coagulants is an extremely dangerous method of treatment, unless all exit of blood from the tumor can be suppressed for some time after the injection has been made. Without this precautionary measure, which is often practically unavailable, embolism may confidently be looked for. Excision, while often a dangerous because a bloody operation, is really the only thoroughly reliable measure, but it should not be lightly undertaken. Sometimes ulceration, with its accompanying danger of hemorrhage, or a rapid increase in size, or pain from pressure, demands surgical intervention. Under these circumstances suitable incisions should be made well outside of the tumor proper, the flaps should be reflected to one side, and every visible blood-vessel should be secured (both on the distal and on the proximal side) before the tissues which hold the tumor in its bed are finally divided. In this way operative interference may be rendered reasonably easy and safe. When the growth is located so as to permit compression of the divided borders against firm underlying tissue, it may be nearly circumscribed by the incision, a pedicle containing the main vessel being left for the proper nutrition of the flap. Ligature the bleeding points and raise the flap from its bed, from which it is kept separated by gauze and otherwise dressed until granulation of the respective borders ensues, when it is restored to place and caused to heal by secondary union with limited disfigurement. With union secured, the vessel of the pedicle should be tied or not as, after delay, circumstances may require. Bryant has thus treated several cases with entire satisfaction. When the tumor is situated in the area supplied by the external carotid, ligature of this vessel, ligature of both external carotids, and ligature of the

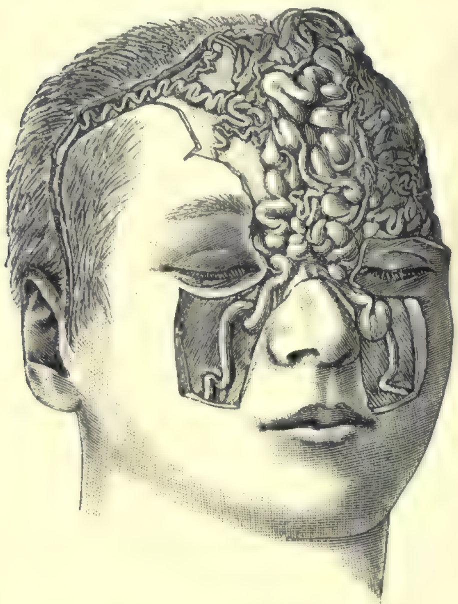

FIG. 173.—Cirsoid Aneurism of the Arteria Angularis et Frontalis on Either Side. (From Lannelongue: "Traité des Kystes Congénitales," Paris, 1891.)

common carotid on the side of disease, have all been tried, but have proved unsuccessful because of free collateral circulation.

Aneurisms.—Aneurisms of the arteries of the face are rare, but, as already mentioned, they sometimes follow contusions. They remain circumscribed unless they prove the starting-point of a plexiform angioma, as sometimes happens.

An aneurism in the region of the face presents the appearance of a small, rounded, pulsating tumor, rarely more than a third of an inch in diameter, readily emptied by pressure or by control of the circulation through the facial, occipital, or temporal artery, and presenting a bluish tinge when it is situated just beneath the mucous membrane or the skin. Appearing, as it generally does, soon after a contusion, such a tumor cannot be anything else but an aneurism.

Prognosis.—Spontaneous cure does not take place, and conversion into a plexiform angioma is rare; at best, a stationary condition is to be anticipated.

Treatment.—Incision and removal of the sac after proximal and distal ligation of the vessel constitute the only proper treatment.

Lymphangiomata.—Lymphangiomata are probably always antenatal in origin and are present in their earlier stages at birth. As a rule, they increase slowly in size but steadily; they may, however, remain apparently unchanged for a variable period, to resume growth rather suddenly and to enlarge quite rapidly. The dilatation of the lymph vessels may be confined to the skin or subcutaneous tissue, or where the oral or nasal cavities are concerned it may involve all the tissues from the skin to and including the mucous membrane; and when the tumor is located in the temporal region, the ectasia may penetrate the muscles more or less deeply. The overlying integument is so intimately associated with the enlarged lymphatic network that it cannot be moved independently of the tumor. These tumors may be circumscribed, involving only a portion of one lip or one eyelid, or they may be diffused, the temporal, palpebral, and buccal regions and the adjacent portions of the nose being converted into a moderately firm, somewhat compressible featureless mass, covered by skin unaltered in color. In the face, lymphangiomata are usually composed of cavernous spaces; sometimes lymph cysts are present, with more or less enlargement of the lymph vessels themselves. When the cheek alone is involved, the condition is called macromelia; the terms macrocheilia and macroglossia being applied respectively to similar conditions of the lip (either the upper or the lower) and the tongue. (Fig. 174.)

A lymphangioma may occur primarily in one of the eyelids and then may later involve the orbit. As a rule, however, the eyelids are affected only secondarily from a primary source in the cheek. The upper lid, when thus affected, overhangs the eye as a large fold. The truly cystic lymphangiomata may or may not be congenital, in the latter event they develop from the cavernous form. Cystic lymphangiomata may be single or multilocular, and where the skin is most stretched there will be seen the characteristic bluish appearance which is so indicative of a cyst in any region and due to any cause. They are less apt to be or to become diffused than the other varieties of lymphangiomata.

The fluctuations occasionally observed in the size of the tumor result from the entry of cocci, usually streptococci, into the lymph spaces. These micro-organisms gain an entrance either directly through the overlying skin or indirectly by way of the lymph vessels of the mouth or nose.

Fig. 174.—Hypertrophy of the Upper Lip Due to a Lymphangitis that had developed in Consequence of a Chronic Coryza. (" Cliniques Médicales Iconographiques," par Messieurs Haushalter, Étienne, Spillmann, et Thiry, Paris, 1901.)

The subsequent course of these growths varies greatly. In one, for example, resolution, complete or partial, may take place; in another, some or all of the lymph vessels may undergo obliteration, with subsequent shrinkage of the growth; in a third, suppuration may occur; and in a fourth, the occurrence of a rupture or the infliction of a wound may give rise to a free and somewhat persistent flow of lymph. In one case recently seen by the author, repeated erysipeloid attacks with fever were noted, after each of which the thickening of the cheek and both lips increased, thus giving rise to a condition closely resembling elephantiasis in other parts, and it was so diagnosed. Other surgeons have reported similar cases.

Although the author believes that no cases of lymphangioma circumscriptum of the face have been reported, there is no reason why this condition should not be found in this region. As seen in other parts of the body the tumor presents a surface which is uneven from the presence of numerous closely packed vesicles of varying size. The color is grayish or almost black. These patches or tumors measure usually not more than one inch in diameter, although in exceptional cases they may be much larger.

Diagnosis.—An enlargement of the cheek, eyelid, or lip, which is covered by unaltered skin that contains no visibly enlarged vessels, and which may often be lessened in bulk by steady pressure, can hardly be anything but a lymphangioma, and should not be mistaken for a hæmangioma. Circumscribed cystic lymphangiomata, however, are apt to be mistaken for other cystic growths. This error is more excusable when neither mucous membrane nor skin is involved, both of them moving freely over the cyst. Cystic parotid tumors are usually distinguishable from lymph cysts by the fact that in the latter the skin appears thinned and translucent. When the tumor under examination is located in the cervical region, aspiration, by enabling the surgeon to ascertain the nature of the contents removed, may decide the question whether the cyst be lymphatic or branchial. Sometimes, however, it will be necessary in addition to make a microscopic examination of the cyst walls. If the cyst is small and deeply seated in the buccal fat, a cystic lymphoma can readily be mistaken for a pure lipoma.

Treatment.—Circumscribed dilatations and cystic enlargements of lymph vessels may be excised. In selected cases of diffused cystic lymphangiomata, Woelfler's method of treatment (by incision and packing of the cystic spaces) is warranted, despite the dangers of infection and the prolonged discharge of lymph which is sure to follow, owing to the impossibility of completely removing one of these growths, when it is located in the cheek and lip, without at the same time partially or completely destroying the facial nerve. For the more diffused forms electrolysis, thermopuncture, and subcutaneous strangulation by ligature may prove serviceable, or all these methods may serve a good purpose at different stages of the necessarily prolonged treatment. Macrocheilia may be treated in the same way, especially when combined with hæmangiomatous tissue. Excision of a portion of the whole thickness of the lip, followed by suturing of the flaps, may greatly improve the condition in certain cases of macrocheilia, although so long as any diseased tissue remains—either after this or after the Woelfler operation—renewed growth is possible, nay, probable. In that form of macrocheilia in which the tissues are simply hypertrophied by reason of the repeated infections caused by carious teeth, it may be found advantageous to remove a piece of the mucous membrane (together with as much submucous tissue as may seem desirable) by elliptical incisions running horizontally across the lip; but the improvement will not be permanent unless measures are adopted for eliminating all sources of mouth sepsis. In "strumous" children the fissures and ulcers which are so often present on the lips or in the mouth may equally well serve as sources of infection, and should receive proper attention.

The true "double lip," as it is usually seen, appears to be of congenital origin, although it may increase somewhat, probably under the influence of the traction exerted when the protruding fold is compressed by the act of shutting the mouth. The condition is amenable to the same treatment as that just described. Different surgeons have reported tumors of a fibro-sarcomatous, sarcomatous, myomatous, gliomatous, or connective-tissue type, located on the bridge of the nose or over the root of this organ. These tumors are covered with thin, but normal skin, are usually flattened, but may tend to become pedunculated. The chief interest which attaches to them resides in the fact that, owing to deficiency or displacement of the osseo-cartilaginous framework of the nose, portions of these growths are often intracranial—indeed, may be superimposed upon a meningocele. Hence a most careful examination should be made of all tumors in this locality, before any operation is decided upon, lest the surgeon find himself working within the cranium and not on the outside of it, as a cursory examination might lead him to believe.

Acne Rosacea.—Acne rosacea is chiefly of interest in its extreme form of Rhinophyma, but the earlier course of the disease must be briefly considered.

Etiology.—In its milder grades the disease is observed in females at puberty or near the menopause, and also in those who are irregular in their menstruation, who are sterile, or who have some form of uterine or ovarian disease. In males it occurs in early or late adult life. Gastro-intestinal dyspepsia, constipation, and the excessive consumption of strong tea or of alcohol in any of its forms, appear all to stand in some causal relation to this disease. The first changes consist in a passive hyperæmia of the superficial skin vessels; then the capillaries dilate and become hypertrophied, and the sebaceous glands undergo the same alterations. The nodular masses which eventually form consist at first also largely of a neoplastic connective tissue which is almost myxomatous in character and which later gives place to ordinary connective tissue. Some authorities contend that the essential character of the ailment consists in disease of the sebaceous glands, the condition being really seborrhœa hypertrophica.

Symptoms.—A rather dusky hyperæmia first appears on the nose, and then often extends to the cheeks and chin. The hyperæmia is either uniform or assumes irregular, rounded, radiating, or stellate figures. Pressure will discharge the hyperæmia temporarily. Small vessels ramify over the surface, and the altered sebaceous glands display enlarged orifices filled with yellowish inspissated sebum (*i.e.*, seborrhœa exists). The appearances just noted fluctuate with the patient's condition. The erythema, etc., for example, may almost disappear at times, but anything which increases the force of the circulation, especially alcohol, will cause the redness to reappear. If, with the lapse of time, the disease does not disappear, certain permanent changes take place: the blush becomes persistent and of a purplish hue; the small vessels appear as anastomosing, sinuous lines; and nodules of varying size (up to that of a large pea) develop on the affected part. The summits of these excrescences are covered with reddened telangiectatic vessels, or their bases are surrounded by a similar vascular arrangement. Seborrhœa oleosa or common acne is also usually present. When, as sometimes happens, the nose is the part chiefly affected, the organ may attain an enormous size, and to this condition the term "Rhinophyma" is commonly applied. (Fig. 175.)

Fig. 175. — Rhinophyma, or Hammer-nose. (Tillmanns.)

Diagnosis.—Our chief concern here is, not with the fundamental disease, acne rosacea, but with the extreme results which it manifests in certain exceptional cases, and especially in those in which the nose is involved. The telangiectasis, for example, is a feature that is lacking in an ordinary case of acne. Tubercular syphilides, when limited to the tip of the nose, are usually small and of a dull reddish color, but show the same absence of enlarged vessels. They develop somewhat rapidly. They tend to ulceration and scabbing, and the ulcers usually present small, irregularly circular, superficial losses of substance. The resultant scars are rounded and depressed. If the characteristics mentioned are not sufficient to determine the diagnosis, the therapeutic test will settle the matter. The unilateral, painful character and the vesication of recurring facial zoster at once indicate the true nature of the disease. Nasal lupus vulgaris usually starts in early life, is not associated with telangiectasis, ulcerates, and becomes scabbed over, and, in addition, characteristic scars are apt to be present. Lupus erythematosus has a definite, superficially elevated border and a scarlike centre, and is rather symmetrically disposed; in any event, it can be confounded only with the earliest stages of acne, with which we are not now concerned.

Prognosis.—The course is very slow and only rarely reaches the condition last described. When there is no distinctly new formation of vessels and when nodules are still lacking, spontaneous recovery may take place.

Treatment.—During the earlier stages of acne rosacea frequent ablutions with green soap, massage of the integument, and applications of ointments containing various drugs—such as five to ten per cent of sulphur, two to four per cent salicylic acid, or one to three per cent of ammoniated mercury—will often arrest the disease, while linear scarifications serve to destroy dilated vessels, when such are present. For rhinophyma some form of operation is necessary. In some cases wedge-shaped excisions of the hypertrophied tissues constitute the best practice, but in other cases shaving of the growth in sections, until relatively or absolutely healthy tissue is reached, will be found to be indispensable. When healthy granulations have formed, Thiersch skin grafting should be employed as a means of securing permanent healing.

Mucous Cysts.—Mucous cysts form slowly growing, rounded, bluish tumors the covering of which is thinned mucous membrane. They rarely attain a greater size than a split pea. They owe their origin to an obstructed duct of a mucous gland. So far as the face is concerned, these cysts are most often observed on the lower lip.

Diagnosis.—When situated on the lip a mucous cyst may be mistaken for an angioma or possibly for a small aneurism, but its incompressibility will show the incorrectness of such a diagnosis, and, if any doubt remains, a puncture with a fine sewing-needle may be made. This latter expedient, however, should rarely be necessary.

Treatment.—Extirpation of every portion of the cyst wall may be effected by dissection, but this is rarely possible. The same result, however, may be secured by excision of a portion of the cyst wall and destruction of the remainder by the galvano-cautery or the thermo-cautery; or, if these are not available, some form of potential cautery may be utilized.

Echinococcus and Cysticercus Cellulosæ.—It is enough to state that such parasitic cysts may develop in the temporal region, in the cheek, in the orbit, and in the substance of the masseter and temporal muscles. These cysts are not so frequently observed in this country as on the Continent of Europe.

DIAGNOSIS.—To distinguish them from cysts of a non-parasitic origin it is necessary to find, in the fluid withdrawn for diagnostic purposes, either the characteristic hooklets or the daughter cysts. When a single cyst containing clear fluid is found in any of the localities mentioned, it is almost certain that this cyst is of parasitic origin (either the echinococcus or the Cysticercus cellulosæ). Surrounding the cyst is a complete connective-tissue capsule, within which are a laminated, elastic cuticle and a parenchymatous granular and cellular layer.

TREATMENT.—When the cyst is readily accessible, complete removal is indicated; but when this is not possible, owing to the relations of the cyst to important parts or organs, a preliminary injection of a one-half of one per cent formalin solution, followed in a day or so by incision and as complete evacuation of the contents as is feasible, will usually result in cure, especially if the cavity is washed out daily with the formalin solution. H. W. Berend (*Gazette des Hôpitaux*, 1855, p. 171) reports the case of a child, one year old, from whose upper lip he removed, by a small incision, a cysticercus tumor the size of a bean. The wound subsequently healed by first intention. In Virchow and Hirsch's *Jahresbericht*, 1901, I., p. 329, reference is made to two cases of cysticercus tumors of the face reported by Cantoni. In one of these the cyst was located in the frontal muscle near the right eyebrow; in the other it was seated in the left obliquus externus. In both cases the cysts were excised and the presence of hooks determined. Finally, Hirschberg (*Berliner klin. Wochenschrift*, 1870, p. 542) reports a case of cysticercus of the lower eyelid, in which, after the tumor had been excised, the wound healed by first intention.

Sebaceous Cysts.—Sebaceous cysts are comparatively rare in the face. They are most apt to be located near the eye or mouth or in the cheek, although they may appear elsewhere.

ETIOLOGY.—They are retention cysts, resulting from the obstruction of the duct of a hair or sebaceous follicle by fat, sebaceous matter, or necrotic epithelial cells; secondary changes may lead to the obliteration of the duct. For cosmetic reasons sebaceous tumors of the face are never allowed to reach the great size often attained in the scalp. They are either quite firm, not being capable of moulding like putty, or they actually fluctuate. The tumors are spheroidal in shape but somewhat flattened, owing to their being compressed by the remains of the elastic skin, in the deeper layers of which they are developed. They are of uniform consistence throughout, and it is not unusual to be able to detect, in the thinned skin over the growth, a small blackened, comedo-like spot through which the cyst can be entered with the eye end of a fine sewing-needle. After withdrawal of the needle some of the sebaceous contents can be extruded by a little pressure, and thus the true nature of the cyst may be determined. The yellowish-white contents may sometimes be seen through the overlying skin, which is always somewhat attenuated. The pultáceous, putty-like, yellowish or gruel-like contents frequently have a peculiar sour, offensive odor. As in the case of sebaceous tumors located elsewhere, inflammation quite often occurs in these cysts.

Diagnosis.—The rounded form of the tumor, the uniform elastic resistance which it offers, the absence of lobulation, the attachment of the cyst to the skin, while it remains freely movable upon the deeper tissues, and often the detection of the orifice of the enlarged but obstructed duct, which can be penetrated by the needle-probe as suggested, furnish the necessary data for distinguishing sebaceous cysts of the face from tumors of a different nature.

Complications; Sequelæ.—Inflammation often renders it hard to determine whether a simple abscess or an infected cyst is being dealt with, although Sutton claims that an inflamed sebaceous tumor has a characteristic color, viz., "the deep red of a ripe plum." This is of some practical importance, because an inflamed cyst will not remain healed unless perchance its entire wall sloughs out or its lining epithelium is destroyed by the infection. If the history of the case shows that the growth had existed for a long time, that it had presented the characteristics of an atheroma, and that it had steadily but slowly increased in size before the inflammatory phenomena made their appearance, there will be no difficulty in distinguishing correctly between the two conditions.

When, at the operation, all the lining of the sebaceous cyst has not been destroyed, an unhealthy, somewhat fungating, readily bleeding ulcer, with raised margins and high base, is likely to develop. This ulcer simulates epithelioma, although ulcerations of the latter nature are rare as compared to those which result from the rupture of an inflamed scalp cyst.

Genuine epitheliomatous change does take place in sebaceous tumors of the face after rupture following suppuration, and it may also occur in an uninflamed closed cyst. The differentiation of a simple cyst from one that has undergone epitheliomatous change cannot be made with certainty until the wall has ruptured from carcinomatous infiltration, when a fungating ulcer, with elevated, indurated border and infiltrated base, reveals its true nature.

Treatment.—Complete excision is the only proper plan, but at the same time great care must be exercised not to leave behind any portion of the cyst wall. To accomplish this successfully will be found a difficult matter, owing to the tenuity of the cyst walls and the remains of the skin. In those cases in which there is a redundance of skin the operation may be somewhat facilitated, and the likelihood of a rupture diminished, by making two semilunar incisions including the thinnest portions of the skin.

Dermoid Cysts.—These growths are always congenital, but are often so small that they are not detected at birth. They usually make themselves manifest before the third year, but may not develop until puberty. The limiting membrane of these cysts of the face consists of a more or less perfect repetition of the skin structures of the region which they occupy. There is a stratiform epidermis resting upon a corium possessing papillæ, and beneath the derma it is quite common to find a layer of subcutaneous adipose tissue. In many cysts, but not all, sweat, sebaceous and hair follicles will be found, longer or shorter hairs or bundles of these being often detected in the mixture of fatty matter and desquamated epithelial cells composing the cyst contents. Fatty degeneration may proceed so far that the contents consist of pure oil. Instances of cysts of the first and second branchial clefts containing teeth have been reported, but this is very exceptional.

Fig. 176. — Median Dermoid Cyst on the Dorsum of the Nose. (From Lannelongue: "Traité des Kystes Congénitales," Paris, 1891.)

In rare instances the contents of the cyst may be serous in character, and, when this is the case, it is very difficult to distinguish the disease from meningocele. The difficulty is still further enhanced when the bone in contact with the tumor either undergoes absorption through pressure, or, as some teach, is prevented from developing. Deep cup-shaped depressions, at the bottom of which lies exposed dura, are found at such places. Through an opening in the outer wall of the orbit orbital cysts are sometimes continuous with dermoids located in the temporal region.

Fig. 177.— Dermoid Cyst Growing at the Outer Angle of the Orbit. (Bland Sutton, in Rose and Carless: "Manual of Surgery.")

Dermoids of the face result from sequestration of portions of the ectoderm. Those located at the tip of the nose are formed by inclusion of epithelium at the time when the internasal fissures become completely closed. When closure at the surface fails to take place throughout and there still remain sequestrated dermal elements deeper down, there will be found at the tip of the nose a fissure from which hair often protrudes. Dermoids at the root of the nose arise from inclusion of portions of dermal elements during the development of the nasal bones between the cutaneous and cartilaginous layers of the dermo-cartilaginous fronto-nasal process. When the inclusion is deeply seated the nasal bones develop in front of the pinched-off dermal structures, and the dermoid cyst may then finally occupy the frontal sinus.

Sequestration dermoids are commonest in the orbital region, especially on the side toward the temple, but occasionally a dermoid lies partly in the temporal fossa and partly in the depths of the orbit, the connecting portion occupying a defect in the external wall of the orbit. Dermoids also occur at the nasal angle

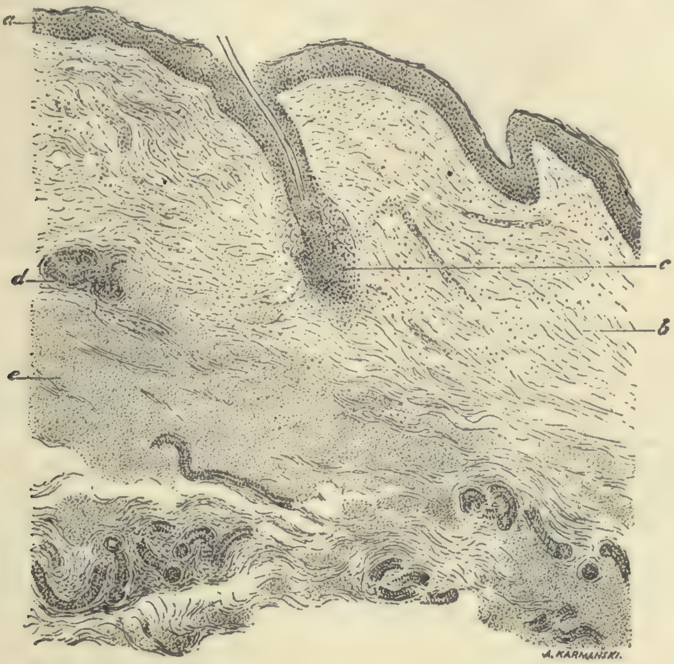

Fig. 178.—Section of the Wall of a Dermoid Cyst. *a*, Epidermis; *b*, dermis; *c*, hair follicle; *d*, sudoriparous gland; *e*, blood extravasation. (From Lannelongue: "Traité des Kystes Congénitales," Paris, 1891.)

of the orbit; and, still more rarely, they are found in the naso-facial fissure, in the intermaxillary fissure near the angle of the mouth, and, farther out in the cheek, in the transverse fissure.

In adults dermoids do not always occupy the typical sites over the fœtal clefts and fissures, because the development of the subjacent bones to which they are attached sometimes materially displaces them. Unlike sebaceous cysts, dermoid cysts are not located in the skin, but lie either just beneath it or beneath the deep fascia or aponeurosis of the occipito-frontalis muscle.

Prognosis.—While it is theoretically possible for an acute pyogenic infection to cause sloughing out of the whole cyst wall, in actual experience this probably never occurs, the final rupture of the cyst being followed either by temporary healing, with subsequent reproduction of the tumor, or by an open, perhaps somewhat fungating ulcer. Pyogenic infection is a rare event and is always the result of a penetrating traumatism. The possibility that malignant disease may develop at the site of the tumor cannot be overlooked; indeed, such an occurrence is by no means uncommon.

Diagnosis.—In most instances the diagnosis is easy. The features which distinguish a dermoid cyst from other tumors are these:—It is congenital in origin; occupies one of the sites of an embryonal fissure; is without the punctum of a sebaceous tumor, which in many respects it resembles; is situated in the deeper layers of tissue, and in its most common sites is in contact with the periosteum; is absolutely unconnected with the skin, and often can be partially displaced sideways, so that the examining finger can feel a shallow, cup-like depression in the bone. In some instances, furthermore, it is possible to mould the tumor by finger pressure, so that it retains for a time the form impressed upon it. When, however, the bone is defective, as it sometimes is in the case of an orbital dermoid, and the tumor rests upon the dura, the pulsating mass is hard to differentiate from a meningocele, for all meningoceles cannot be diminished in size by pressure; but, when this can be done, it is plain that the growth cannot be a dermoid, and one is forced to conclude that it must be a meningocele, especially if cerebral symptoms are caused by forcing the tumor contents partly within the cranium. Doubt as to the nature of the condition rarely arises in dermoids of the face except in those instances in which the tumor is located at the nasal angle of the orbit or over the root of the nose. In these cases the presence of pulsation in the mass and the fact that its size cannot be materially altered by prolonged firm pressure, *despite the markedly cupped condition of the bone or the evidences of a large opening in the bone with sharply defined margins,* should prove that the pulsation is conveyed to the cyst because it rests upon the dura; for, in the case of a real meningocele, serious difficulty in emptying the tumor will be experienced only when the opening of communication in the bone is very small. Orbital dermoids are most difficult of differentiation. The discovery of protruding attached hairs after the cyst has ruptured in consequence of suppuration, or the casting out, as the result of pressure made upon the tumor, of masses of hair with the characteristic cyst contents, will show that the condition is not that of an ordinary abscess or sinus.

Fig. 179.—Cornu Cutaneum of the Cheek. About two-thirds natural size. (From Treves' "Operative Surgery.")

Treatment.—Careful dissection to remove every portion of the cyst wall is essential, and should be done as soon as possible during childhood to permit of the proper development of the subjacent bone. Due precautions must be taken not to injure the dura when the cyst lies in contact with it, but the two are usually easily separable. Orbital dermoid cysts frequently require temporary osteoplastic resection of the outer wall of the orbit. (For further details see the articles on "Surgical Affections of the Head" and on "Surgical Affections of the Eye" in the present volume.)

Cutaneous Horns; Cornua Cutanea.—The scalp is the most common situation of the cephalic horn; next in order of frequency come the forehead, the temples, and last the ear. In a few cases the growths have been observed on the upper eyelid and on the cheek immediately below the inner angle of the eye. These horns are composed of dense columnar masses of epithelium often springing from elongated papillæ. Sometimes there is a concentric arrangement of the epithelial cells, such as is seen in corns. The horns may be single or multiple, straight, twisted, or irregular, and are of various colors, the usual tints being yellowish-brown or brownish-black. The exterior is fissured or longitudinally grooved, and the horn may project only a short distance above the integument or be several inches in length. The bases of such horns show depressions corresponding to the valleys between the hypertrophied papillæ. Sometimes the horn originates from a diseased and dilated sebaceous-gland follicle. When not inflamed these outgrowths are painless, but when they are irritated their bases become tender and painful and may undergo an epitheliomatous change.

Fig. 180.—Cornu Cutaneum of the Face. (After Mracek.)

Cutaneous horns start either from an atheromatous cyst or from a local hypertrophy of the papillæ of the corium. The true cause of the excessive cornification manifested by these horns is not known, but it can often be shown that local irritation of one kind or another bears a relationship to the process.

Prognosis.—While cutaneous horns sometimes spontaneously drop off, never to return, this is unusual. Recurrence is the rule, and Lebert claimed that as many as twelve per cent become epitheliomatous. Hence radical treatment should be urged.

Treatment.—Free removal of the growth, with destruction of its base by excision or by the use of the cautery, is the only proper course to pursue.

Adenoma.—Benign epithelial neoplasms of the skin of the face originate either from the sebaceous or from the sudoriparous glands.

ETIOLOGY.—A certain number of these tumors are congenital in their origin; as regards the others it is not known what the exciting cause is. An adenomatous condition, affecting a limited portion of the tumor, has been observed in other kinds of new-growths.

SYMPTOMS.—Acquired sebaceous adenomata occur almost exclusively in the old and are usually located on the forehead and alongside the nose. They are sessile in character, oval, spheroidal, or even acuminate in shape, and they vary in size from that of a pin's head to that of a pea. They are covered by skin of the same tint as that of the neighboring parts. Congenital adenomata grow slowly but steadily, being apt to enlarge more rapidly about the period of puberty. While they generally occupy the sites mentioned, they also are sometimes found on the chin or near the mouth. They may reach a somewhat greater size than that attained by the acquired form, and yet at times they are extremely small. Unlike the adenomata of the acquired variety, they are of a "yellowish-white, a deep brownish-red, or a bright crimson color." (J. C. Warren.) Slight telangiectases may be observed in them. Upon section it is seen that the tumor consists, in the larger growths, of a convoluted mass of tubules, while in the smaller ones the arrangement is that of an ordinary sebaceous follicle.

Sudoriparous adenomata appear by preference near the angle of the eye or jaw. There seems to be no special tendency to ulceration in this or the sebaceous form unless it becomes infected through an open traumatism, when a chronic ulcer not uncommonly results. Such ulcers are suggestive of malignancy and, as a matter of fact, they sometimes serve as the starting-point of epithelioma. In the majority of cases, however, they prove to be non-malignant in character. These sudoriparous adenomata usually form circumscribed, nodular, grayish masses, covered by normal skin.

DIAGNOSIS.—It is not possible, as a rule, to ascertain the true nature of these adenomata of the face until an opportunity is afforded of examining sections of the tumor with the microscope. (See Surgery of Skin Diseases, in Vol. II.)

TREATMENT.—When the tumor is of small size (no larger, for example, than the head of a large pin) electrolysis will be found sufficient for its destruction; but when the growth is of larger size excision is advisable.

B. MALIGNANT TUMORS.

Sarcoma.—Sarcoma of the skin of the face will alone be considered here. Tumors of this nature may be congenital or they may appear at any subsequent period of life. The varieties observed have been the myxosarcoma and the angiosarcoma. The particular localities affected were the eyelids, nose, lip, and chin. All forms tend to early generalization, although the congenital tumors ordinarily develop most rapidly and begin to spread earliest.

Symptoms.—A true sarcoma usually appears in the form of a nodule covered by skin that is thinned but not otherwise altered in appearance. Later, the tumor becomes lobulated and, while it is commonly sessile, it shows in some cases a tendency to become pedunculated. The pigmented form usually arises from an irritated pigmented nævus, sometimes from a pigmented wart. In this form the growth is generally rapid from the outset, but in the non-pigmented varieties (except in a sub-class presently to be described) the increase in size is gradual at first, while later it rivals, in the rapidity of its growth, the pigmented form. Regional infection soon occurs in all forms, new growths appearing in the neighborhood of the primary focus. After a varying length of time the skin becomes adherent, reddened, tender, and œdematous, and at the same time the tumor becomes fixed to the deeper parts and is therefore less movable. Ulceration next sets in, an offensive discharge appears, and the base of the ulcer presents fungating growths. The regional lymph nodes are nearly always enlarged.

The neoplasms described under the different designations of idiopathic multiple pigmented sarcoma of Kaposi, plexiform and alveolar sarcoma, angiosarcoma, and cylindroma of the skin, are, at least in many instances, really endotheliomatous and less malignant than the more clearly marked sarcomata. They are apt to be slow in growth, well encapsulated, and hence freely movable; the lymph nodes almost invariably remain uninvolved. Their usual sites are the cheek, the nose, and the lips.

Diagnosis.—In the pigmented form the diagnosis is easy, as the rapidly enlarging, variously pigmented, rounded, lobulated or almost papillomatous character of the growth, the presence of an ulcer with fungating base, and the generalized dissemination, with probable or certain involvement of the viscera, are distinguishing features that do not belong to any other local disease of the face. In the non-pigmented form of sarcoma the appearance of a cutaneous or subcutaneous whitish, nodular growth, covered with unaltered and unattached skin, the rapid development of the tumor, its tendency to both local and general dissemination, and the enlargement of the related lymph nodes, should exclude lupus, syphilitic gumma, epithelioma, and fibrous growths. While no positive clinical line of demarcation can be drawn between sarcomata and endotheliomata, the latter can usually be distinguished from the former by the following characteristics: their slow growth, their distinct encapsulation, their appearance at any age, and the further fact that the related lymph nodes are almost never enlarged. When endotheliomata are completely encapsulated they rarely recur after excision.

Prognosis.—The prognosis in sarcoma of the face is very bad, death occurring soon from exhaustion, toxæmia, or the involvement of some organ essential to life. The prognosis in a well-encapsulated endothelioma is decidedly better.

Treatment.—The hypodermatic administration of Fowler's solution of arsenic in gradually increasing doses is still looked upon with some favor, but it offers scarcely any prospect of a permanent recovery. Circumscribed growths should be freely excised. In inoperable primary growths Coley's toxins, aided by the *x*-ray, offer a certain measure of hope. Evidences of generalization should negative any operative procedures. When the tumor is of the endotheliomatous type excision is good practice. Possibly Coley's toxins, with the *x*-ray, may cure a few cases, or at least effect temporary relief, even after some dissemination has taken place.

Malignant Epithelial Neoplasms.—Under this heading may properly be grouped the different cancerous or precancerous conditions to which the terms keratosis senilis, squamous-celled epithelioma, and rodent ulcer or Jacob's ulcer, are applied. Of each of these we shall here give brief descriptions.

Keratosis Senilis.—In this condition hypertrophy of the epidermis in certain areas forms thin, dark, yellowish, horny patches, beneath which superficial ulcerations may appear. The changes which take place in the skin resemble those which occur in the superficial form of epithelioma; indeed, keratosis senilis often is really the first stage of rodent ulcer, and, if this clinical fact be borne in mind, malignant disease may often be averted or its ravages be limited.

Aside from the disfigurement which it causes, epithelioma entails a real danger to life. Hence the importance of properly treating what may prove to be its first stage, viz., the keratosis senilis. To accomplish this object it is necessary that the part should be washed daily with soap and afterward anointed with a little diachylon ointment. Occasionally sapo viridis should be substituted for the ordinary toilet soap. If slight ulcerations develop beneath the corneous patches of epithelium, the diseased area should either be freely excised or be thoroughly destroyed by the thermo-cautery or some form of potential cautery; for with the appearance of this ulceration we have a right to believe that the initial stage of rodent ulcer or of superficial epithelioma has actually begun.

Squamous-celled Epithelioma.—A squamous-celled epithelioma may originate in the epidermic strata, the rete, the hair follicles, or the cutaneous glands. Its true etiology, like that of all malignant disease, is as yet undetermined. Nevertheless, it must be admitted that a slight traumatism—such, for example, as that inflicted by the hot, rough stem of a clay pipe or by the heat of a lighted cigar kept for long periods in contact with the delicate epithelium of the lip—or even the irritation supplied by the moistened tobacco, is sufficient to create a locus minoris resistentiæ.

From a clinical point of view it is necessary to distinguish three forms of epithelioma: the superficial, the deep-seated, and the variety to which the term "papillary epithelioma" (erroneously called "malignant papilloma") is applied.

Superficial Epithelioma.—In this form of epithelioma there is a slow infiltration of the superficial portion of the skin with epithelial elements which tend to spread centrifugally. Very long periods elapse before the subcutaneous tissues are attacked. The regional lymph nodes only late, if ever, become diseased. While in their early stages all superficial epitheliomata apparently are identical in nature and primarily involve the tissues of the face to the same depth, at a later stage they assume clinically two fairly well-characterized forms or varieties.

In the first of these varieties the disease presents itself in the form of nodules or flat discs which are located chiefly in the epidermis; the term "discoid carcinoma" often being given to these cases. Or the disease may manifest itself first in a benign lesion like a mole, a wart, a nævus, a chronic fissure of the lip, a patch of chronic eczema, an old syphilitic scar, or a tuberculous ulcer—a lesion, in short, which may have been present for many years; and then the malignant changes may advance with great rapidity, causing deep infiltration of the tissues, involvement of the related lymph nodes, and eventually (in from two to five years) death.

The second variety, which is called "rodent ulcer," progresses very slowly; it may, in some cases, last for two-thirds of an ordinary lifetime and does not involve the lymph nodes.

While in the vast majority of instances superficial epithelioma of the rodent type always remains the same disease, certain cases of epithelioma which at first conform to the clinical type of rodent ulcer are really superficial epitheliomas of a different type, only requiring favorable conditions to demonstrate their essentially different nature. This is not invariably true, and genuine rodent ulcer occasionally, although rarely, does pass over into the other forms.

FIG. 181.—Rodent Ulcer Involving the Larger Part of the Nose and a Portion of the Adjacent Cheek. At the time when the photograph was taken the disease had already been in existence for many years. (University Hospital, Ann Arbor, Michigan.)

RODENT ULCER; JACOB'S ULCER.—(Fig. 181.)—Rodent ulcer is most frequently situated at the inner canthus of the eye, on the side of the nose, in the temporal region, or on the cheek near the ear. While it may originate from a patch or patches of keratosis senilis, it commonly appears as a yellowish-red thickening of the skin. This continues to extend as a flattened nodule which becomes centrally abraded and degenerates into an ulcer, originally rounded, but later irregular in outline. The base and margins are indurated, the latter being clean-cut, somewhat abrupt or rounded, firm, and slightly elevated and everted. The base of the ulcer is smooth or slightly granular, dry, and glossy, as if varnished by the scanty viscid secretion; but, from time to time, it will be found covered with a dark brown, bloody scab. The condition is attended with little or no pain and the disease is almost never spontaneously arrested, although cicatrization may appear at spots, and in some rare instances, after the lapse of many years, a cure may result. Although the disease may not reach its maximum development before the end of from twenty to thirty years, and then may continue afterward in a quiescent state, it may at any time commence to infiltrate rapidly and deeply. In its usual slow form, the disease may cause extensive destruction of skin, cartilages, and bone, until at last the orbits, nose, and mouth form one crater-like opening. The lymph nodes remain normal. In the most advanced and severe cases it not uncommonly happens that through ulcerative action an opening is made in one of the larger blood-vessels and that a sharp hemorrhage follows.

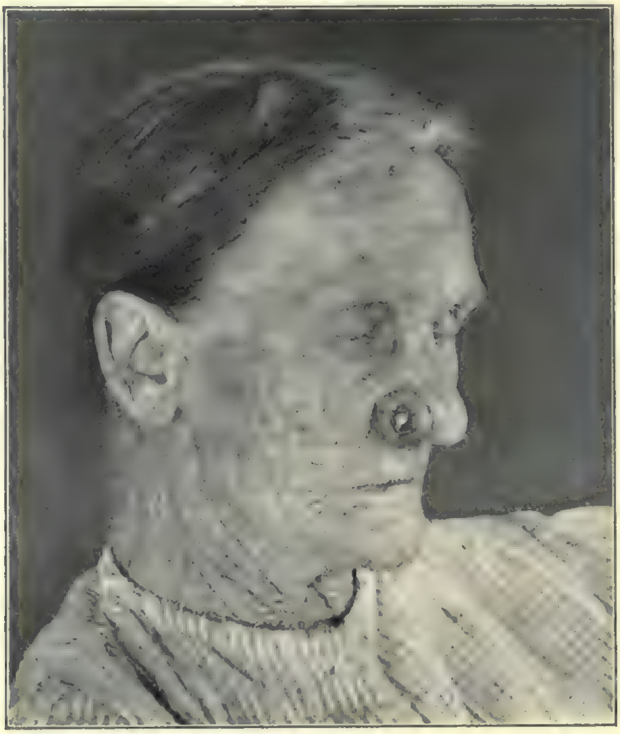

Fig. 182.—Carcinoma of Ala Nasi. (University Hospital, Ann Arbor, Michigan.)

Deep-seated epithelioma—(Figs. 182, 183, and 184) begins as a small reddish tubercle, a warty growth, or a hard, thick, flattened plaque, involving the entire thickness of the skin and subcutaneous tissue, and the base of the resulting ulcer is infiltrated and indurated. Pain is often marked, lymphatic involvement takes place sooner or later, and death results from exhaustion due to pain, discharge, and septic absorption. The lips, nose, eyelids, forehead, and scalp, as well as old cicatrices and lupous ulcers, may be attacked by epithelioma. Ulceration eventually ensues, fissures or excoriations forming through the disintegration of the central portions. Usually the ulcer is crateriform, with elevated, irregular, pearly, ridge-like, everted, knobby and sinuous borders, although sometimes the margins are clean-cut and about level with the skin. The base is infiltrated, irregular, granular, and often covered with grayish or yellowish sloughs. It always presents an unhealthy appearance, bleeds readily, and secretes a scanty offensive fluid. Occasionally, separate tumors form at some little distance from the primary growth, apparently healthy tissues intervening. In reality, however, these tissues are cancerous, although in a less advanced stage of development. The regional lymph nodes become involved, but relatively late in many cases, and in *very* rare instances the enlargement proves to be due to pyogenic infection, as shown by the disappearance of the swelling after the ulcerating growth has been removed.

Papillary epithelioma constitutes another variety of epithelial cancer. It is a pedunculated or sessile growth, usually papillomatous, not always hard, indeed sometimes rather spongy in character. Occasionally the papillary form is not assumed, the growth having a smooth surface. As a rare event, according to Hyde, the superficial epitheliomatous process extends widely instead of deeply. In its advance it may involve the brows, cheek, and chin, the parts invaded being "interspersed with raised cicatriciform areas, suggesting that ineffectual attempts had been made to check the disease by surgical measures. The apparently atrophic discs, mingled with vascular, florid, fungiform, pyriform and oddly shaped outgrowths, are really cancerous infiltrations of the type of discoid epithelioma. They may be seen gluing the lobe of the ear to the cheek, or everting the lower lid, even when superficial papillary vegetations are the predominating features of the disease."

Fig. 183.—Epithelial Cancer of Temporo-malar Region. (University Hospital, Ann Arbor, Michigan.)

Diagnosis.—Lupus vulgaris may be confounded with epithelioma, but the early age at which lupus is observed and becomes widespread aids greatly in the differentiation. Lupus ulcers are often environed by secondary tumors, and the discharges are purulent rather than scanty and viscid, being without the characteristic carcinomatous odor. Furthermore, they have not the dense, indurated, everted margins of the epitheliomatous ulcers, with apparently normal circumjacent integument. Syphilis occurs as a rule in younger individuals, pursues a more rapid course, and is usually painless. The history (when obtainable), the multiplicity of lesions, the generally indolent nature of the lymph-node involvement if it happen to be present, the typical reniform, crescentic ulcers and cicatrices, and the marked tendency to heal, especially with antisyphilitic treatment, serve to exclude epithelioma.

Prognosis.—The prognosis is grave, but when the disease occurs early and is radically treated,—*i.e.*, when, as in carcinoma of the lower lip, all diseased struct-

Fig. 184.—Carcinoma of the Cheek and Lower Eyelid. (University Hospital, Ann Arbor, Michigan.)

ures are thoroughly removed,—something very like a favorable prognosis may be given. Upon a rough estimate it may be stated that at least two-thirds of the cases of epithelioma of the lip may be cured by operation. The more superficial forms occupying some other part of the face besides the lip, should, under similar conditions, give even better results. Unfortunately, the fear of denuding large surfaces which may afterward heal only in part, and the dread of leaving extensive scars if the effort is made by plastic operative work to secure primary cicatrization without distortion of the mouth or eyelids, are factors which militate against the best results. Surgeons are urged, first, to get well outside all disease, deeply as well as superficially, and then boldly to trust to large Wolfe grafts whereby often extensive areas can be securely healed with the minimum of deformity. Even if complete primary failure occurs, repetitions of the procedure or the employment of Thiersch grafts may finally secure the desired results. The author once obtained a complete primary success, in an extensive epithelioma of the temporal region, by employing a Wolfe graft over three inches long by a little less than three inches wide. A portion of the base of the excised area to which this Wolfe graft was applied was bone denuded of periosteum.

When the gums are attacked, and still more when the jaws are involved, the outlook, even after free excision of bone, is most unfavorable. Extensive involvement of the lymph nodes, especially when they are fixed by perinodular infiltration, renders a cure impossible.

Fig. 185.

Fig. 186.

Fig. 185.—Partial Destruction of the Nose after Caustic Treatment for Carcinoma. (University Hospital, Ann Arbor, Michigan.)

Fig. 186.—Partial Repair by Plastic Operation and Wolfe Grafts of Destructive Effects of Caustic for Carcinoma of Nose. (University Hospital, Ann Arbor, Michigan.)

Treatment.—This depends upon the variety of the neoplasm and the complications. Phototherapy, radium, and the x-ray should be employed only for the more superficial forms, or where removal of the lesions would entail ectropion or more than usual deformity, as when they are located on the bridge of the nose. These methods are slow and uncertain. Free excision, with the removal of the regional lymph nodes, whether apparently diseased or not, is indicated for the more severe forms. For the early stages of rodent ulcer, freezing, curettage, the application of pyrogallic acid or of caustic potash, or excision will usually suffice. For the superficial discoid form, when it is possible to distinguish it clearly from rodent ulcer, free excision, with clearing out of the affected lymph nodes, should be done. For inoperable growths the forlorn hope of the x-ray or possibly of the pancreatic ferments (which are

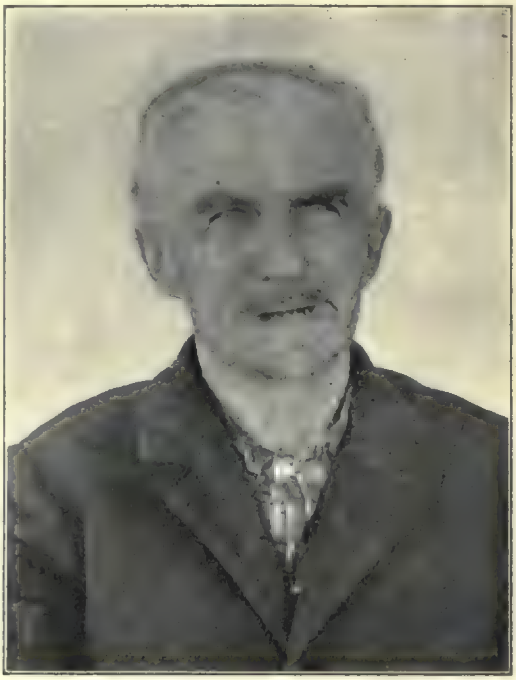

FIG. 187.—Shows Result of Syme's Method of Reforming the Lower Lip after it has been Completely Excised for the Eradication of Carcinomatous Disease. (University Hospital, Ann Arbor, Michigan.)

now under trial) alone remains. Local and purely palliative operations are of course available at all times.

Recurrent carcinomata should be treated on the same general lines, some form of caustic or the actual cautery being oftentimes preferable to the knife. (Figs. 185, 186, and 187.) Many other destructive agents besides those instanced may be employed, but information regarding these agents and also regarding the surgical procedures required for the plastic repair of the defects left by excising malignant growths, must be sought in other sections of this work. (See Vol. II. [article on Surgery of Skin Diseases] and Vol. IV. [article on Plastic Surgery].)

CONGENITAL FACIAL DEFECTS.

It will not be necessary here to enter fully into this subject, as the article on Hare Lip and Cleft Palate, in the present volume, is devoted to the consideration of all those defects which are of surgical interest.

Macrostoma and Microstoma.—In macrostoma incomplete closure of the transverse fissure leaves too large a mouth; in microstoma this cleft unites too far forward, with the result that the mouth is too small. (See article on Plastic Surgery in Vol. IV.)

Fistula of the Lip.—An incomplete closure of the soft parts composing the upper lip may lead to the formation of a blind track lined with mucous membrane and directed upward toward the nostril. The external opening is apt to

Fig. 188.

Fig. 189.

Fig. 188.—Kraske's Case of Oblique Facial Cleft; or, rather, Cicatricial Deformity along the Line usually Traversed by such a Cleft. (From Rose and Carless: "Manual of Surgery.")

Fig. 189.—Macrostoma with Auricular Appendages. (After Fergusson, from Rose and Carless, "Manual of Surgery.")

be on the red border of the lip, at the junction of the philtrum with the outer segment of the lip—*i.e.*, at the point where the soft parts covering the superior maxilla and those of the corresponding intermaxillary bone fuse. The condition is of very rare occurrence. Where the fistula is located in the lower lip it does not seem possible to give any satisfactory explanation of its mode of origin. These fistulæ are usually double, instead of median. Hence it is not permissible to refer their origin to the failure of a median cleft to close.

Goldflam* reports an instance of a congenital fistula on each side of the median line of the lower lip. At each of these points there was a sac-like dilatation of a fistulous channel which opened externally. The father, a brother, and a sister presented the same anomaly.

* Muenchener medizinische Wochenschrift, January 8th, 1907.

In the treatment of facial fistulæ and clefts the fundamental idea should be to dissect out every trace of the lining mucous membrane, and then to repair the consequent defect by simply suturing the edges of the wound or, if necessary, by performing a suitable plastic operation. (See the article on Plastic Surgery, in Vol. IV.)

Rare Deformities in the Region of the Nose.—(Figs 190, 191, and 192.) Three instances of an unusual form of facial deformity have been described by Dr. L. Kirchmayr in the *Deutsche Zeitsch. f. Chir.*, January, 1906. They may be briefly described as follows:—

Fig. 190. — Rare Facial Deformity. (L. Kirchmayr in *Deutsche Zeitschrift für Chirurgie*, January, 1906.)

In a well-developed, healthy girl of four months a wide cleft passed through the left side of the upper lip and extended through the hard and soft palates to the outer side of the left intermaxillary, which, somewhat crumpled, projected into the cleft. The latter, instead of opening directly into the alveolar and palatal cleft, was bridged across by a well-formed ala nasi, behind which existed a fairly large communication between the oral and nasal cavities. The left half of the nose appeared normal except in one respect, viz., that the under part, corresponding to the cleft in the lip, exhibited no evidence of a nasal cavity. From the inner portion of the roof of the left

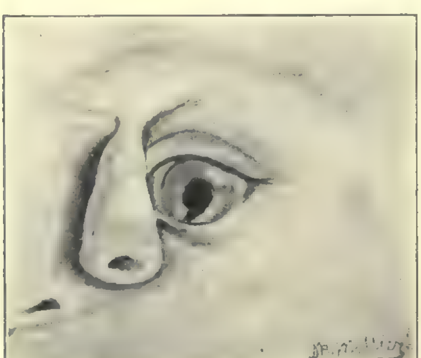

Fig. 191.

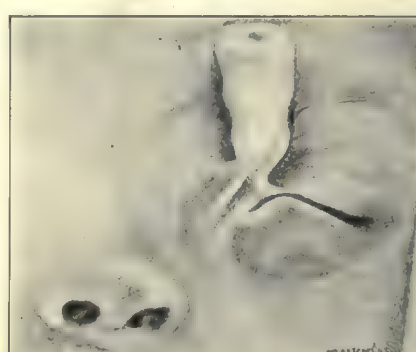

Fig. 192.

Figs. 191 and 192.—Enlarged Views of the Condition Shown in Fig. 190. (L. Kirchmayr, in *Deutsche Zeitschrift für Chirurgie*, January, 1906.)

orbit, however, there hung (Figs. 190–192) a long, "snout-shaped," cylindrical structure with an ovoidal extremity. It was funnel-shaped, as shown in the cut, and was covered with fine hairs. At its point of origin it enclosed a cone about 0.5 cm. ($\frac{1}{5}$ in.) long, cartilaginous below, but osseous for a short distance above. A probe could be passed through the small opening at the distal end of the funnel-shaped object and pushed on until it reached the cartilaginous cone. The cavity, it was found, was lined with mucous membrane.

Selenkoff's case, quoted by Kirchmayr, was that of a man, thirty-six years of age, in whom the right half of the nose was replaced by a "snout-like" process similar to that seen in the first case. The alveolar border and palate showed no cleft. Some teeth were missing. The ethmoid and its cribriform plate, the frontal sinus, the right nasal bone, the lachrymal canal, etc., were absent on the right side.

The third case quoted is that of Landow. It resembled quite closely the preceding case, but the patient was an infant only five weeks old. After thoroughly discussing all the points of interest relating to this case Kirchmayr makes the following remarks:—"Putting essentials together, then, we have in these cases deformities which are characterized by the fact that all exhibit defective formation of the lids and a snout-like formation of the medial, upper surface of the orbit of the same side. In addition to these easily recognizable deformities there existed others in the region of the fissure between the nasal and upper maxillary processes and also in the region of the oblique face fissures. All of the deformities, it must be assumed, owed their origin to an injury inflicted upon the region of the fissure, perhaps over a very limited area,—an injury which must have been of a serious character although of only short duration, and of which we can only say that it must have been inflicted during the first weeks of development; of its more precise nature we know nothing."

Unilateral Facial Hypertrophy. — Unilateral facial hypertrophy is a disease of rare occurrence. It is of congenital origin, and may involve the bones alone, or the soft parts alone, or both of these tissues simultaneously. The disease is in reality an inherited partial gigantism, and is occasionally complicated by similar enlargement of one or more of the extremities. In the illustration (Fig. 194) is seen an excellent example where a congenital growth, partly excised at fifteen years of age, continued to grow until it presented the appearance

Fig. 193.

Fig. 194.

Figs. 193 and 194. — Case of Congenital Hypertrophy of One Side of the Face. (Ernst Pagenstecher, in *Deutsche Zeitschrift für Chirurgie*, May, 1906.) Fig. 193 shows the extent to which the disease had already developed at the age of four or five. Fig. 194 shows the condition of the disease at the age of thirty-five.

shown in the picture. Already in early childhood, as may be seen in Fig. 193, considerable deformity existed.

In the case which is now under consideration, the condition, at fifteen years of age, was diagnosed and operated upon as lipoma of the cheek. Later, the continued growth of the upper portion of the tumor, with enlargement of the upper jaw and malar bone, led to the correct diagnosis.

Unlike what takes place in leontiasis osseum there is, in unilateral facial hypertrophy, immense hypertrophy of the soft parts, without any cranial enlargement or encroachment of the hard parts on the orbital and nasal cavities. In the next place, the enlargement of the soft parts is clearly not due to angiomatous, lymphangiomatous, or cavernous growth, but to increase in bulk of all the soft parts, although cystoid spaces in the connective tissue may be found. When the osseous enlargement predominates and the soft parts actually become atrophied, the condition can hardly be misunderstood. The upper jaw is apt to be symmetrically enlarged and presents essentially its normal depressions and elevations, while the alveolar border is enlarged and the upper teeth tend to overlap those of the inferior maxilla, which usually is also hypertrophied, as is the malar segment of the zygomatic arch. Irregular dentition, both as to number and as to form of the teeth, is common. The mucous membrane is apt to be hypertrophied, and, by bulging between the jaws, it is liable to frequent crushings or bruisings, in consequence of which polypoid excrescences may form and may protrude from the angle of the mouth. (Fig. 195.) The tongue as a whole may also participate in the hypertrophy, being much enlarged upon the diseased side and bearing "thick, widely separated papillæ." * A peculiarity observed in more than one case is that, after maturity has been reached, the increase of the swelling continues and may even take place at an accelerated rate.

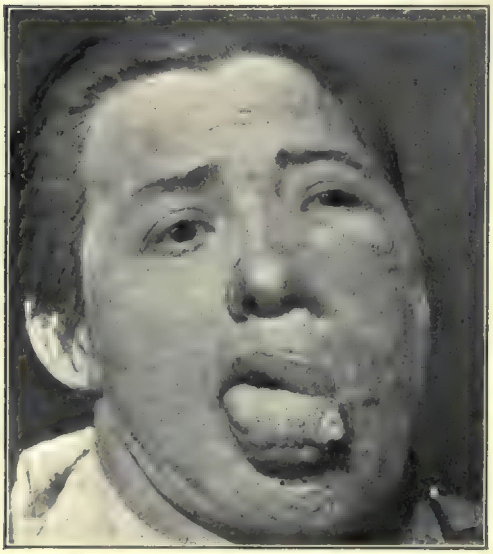

Fig. 195.—The Same Patient (Fig. 194), with the Tongue Protruded.

Diagnosis.—The diagnosis must rest in large measure on the unilateral character of the enlargement and on the absence of involvement of the orbital and nasal fossæ. When the soft parts are chiefly involved, the exclusion of lymphangiomata and hæmangiomata, and of cystic, fibrous, and other growths, and

* Dr. E. Pagenstecher, in Deutsche Zeit. f. Chir., May, 1906.

the evident congenital origin, before bone and tongue hypertrophy can be detected, would seem to furnish the only data by means of which we may arrive at a correct conclusion. Hemiatrophy of the face is scarcely likely to be mistaken for unilateral hypertrophy.

Treatment.—The treatment must depend upon the special features presented in each case, and consists in properly planned resection of the redundant soft tissues. It seems hardly necessary to mention the fact that the facial nerve or some of its most important branches must almost necessarily suffer from such operative interference.

HARE LIP AND CLEFT PALATE.

By JAMES S. STONE, M.D., Boston, Massachusetts.

Etiology.—A definite knowledge of a few facts in embryology is essential to a clear understanding of hare lip and cleft palate.

The first indication, in the embryo, of the development of the mouth is the formation of a depression on the twelfth day. During the third week the first and second visceral arches appear, growing forward from the sides of the head toward the median line. The first visceral arch on each side divides into a larger mandibular arch, which by union with its fellow forms later the lower jaw and lip, and a smaller maxillary process. As these structures grow, the future mouth becomes more clearly defined, lying above the mandibular arch and between the maxillary processes.

Meantime another process has grown out as an unpaired structure above the future mouth. As this process grows there appear, on each side of it, two ridges bounding depressions which later become the nostrils. The outer set of these ridges, which are called the lateral frontal processes, later become the alæ of the nose. As they grow they project out just inside of the maxillary processes, being separated by a depression reaching up and out to the eye. The inner set of these ridges, which lie next each other, is called the naso-frontal process. It later forms the intermaxillary portion of the upper jaw, the nasal septum, the bridge of the nose, and the central portion of the upper lip.

At the end of six weeks the maxillary processes should have united with the lateral frontal processes and with the naso-frontal process. By the end of the second month the boundaries of the lips and nostrils should have been completed.

A failure of union between the maxillary process and the naso-frontal process produces a hare lip, which may occur at one or both sides of the median line.

A failure of the maxillary process to unite with the lateral frontal process produces a coloboma. An imperfect fusion of the mandibular arch may produce a median defect in the lower lip—a very rare deformity. In extremely rare instances a true median hare lip is due to a defective fusion of the two halves of the naso-frontal process.

The palate is formed by the growth inward of two lateral shelves from the sides of the upper jaw. In the eighth week the fusion of these two shelves should begin in front. By the eleventh week union should have occurred throughout the hard and soft palates. At about the same time the halves of the uvula develop and unite normally.

As the union of the sides of the palate begins in front it is plain that cleft of the soft palate alone is more common than cleft of the hard palate alone. It is possible, however, to have failure of union in any portion of the palate.

While obviously hare lip and cleft palate are due to arrests of development, it is impossible to say what causes the arrest.* In very rare instances congenital tumors of the tongue have been associated with these defects. The theory of amniotic adhesions has certain facts to support it, especially the frequent association with other defects which may be explained in the same manner. Heredity, beyond question, plays an important part in hare lip and cleft palate. The defects seem especially common among the first children of immature parents. Beyond this, nothing definite can be said in regard to the cause of the lesions. It may be well, however, to call attention to the fact that the defects are the result of failures of development occurring in the very early weeks of pregnancy. Here, as in so many other congenital defects, the so-called maternal impressions are almost invariably received long after the time at which the arrest of development occurs.

I. HARE LIP.

Varieties.—Hare lip is one of the more frequent anomalies, occurring about once in two thousand four hundred births. It may be either single or unilateral, or else double or bilateral. In either case the defect may be simple, involving the lip alone, or complicated, the alveolar process being involved. Among these general groups there is an infinite variety of individual forms. The defect is somewhat more common on the left than on the right side.

In the simple unilateral cases the defect may appear merely as a slight fissure near the mucous border of the lip. More rarely, it may appear as a vertical thinning or grooving of the entire lip along the line of fusion. (Fig. 197.) In most cases of partial hare lip the defect involves about one-half or two-thirds of the height of the lip. But, however slight the extent of the defect in the lip, there are practically always present three prominent characteristics which are of the utmost importance in treatment. On the defective side the nostril is broadened and flattened, the septum of the nose is deviated toward the sound side, and the thickness of the lip below the nostril is diminished where not completely absent.

In single hare lip complicated by cleft in the alveolar process the deformity almost invariably involves the entire height of the lip from the mucous border to the nostril, although there may be a little bridge of skin at the edge of the nostril. The width of the gap varies greatly, depending largely on the extent of the defect and the amount of the deformity in the alveolar process. In some instances there is only a slight irregularity in the border of the alveolar

* Some embryologists maintain that the intermaxillary bone in man normally is only rudimentary and bears no teeth. In certain animals the intermaxillary or premaxillary bone is distinct from the maxillæ, and bears incisor teeth. If this view is correct, then hare lip and cleft alveolar process are to be explained, not as an arrest of development and of fusion of the component parts, but as a reversion to an ancestral type.

process without any displacement. In others the free side of the intermaxillary bone is swung far outward, forward, and slightly upward, away from the alveolar process at the outer side of the cleft. (Fig. 196.)

In double uncomplicated hare lip the deformity varies with the development of the central portion of the lip, which grows from the intermaxillary bone. The central portion may be very small indeed. It seldom extends downward for the full normal height of the lip. (Fig. 197.) It is not uncommon to find on one side a complete fissure extending into the nostril, and on the other side only a slight defect in the border of the lip. In rare instances there is a complete absence of the central portion of the lip, which grows just below the septum. (Figs. 198 and 199.) Such cases are often spoken of as having a median hare lip. While this term is anatomically correct, it is not so embryologically. More properly these are cases of double hare lip with absence of the central or intermaxillary portion. (Figs. 200 and 201.)

Fig. 196.—The Ordinary Type of Single Hare Lip, with Cleft of the Alveolar Process and of the Palate. On the affected side the ala is flattened and the nostril is much broadened. The septum is deviated toward the sound side, owing to the union between the septum and palate on that side. The tip of the nose is not so much deviated to the sound side as is the base of the septum. The intermaxillary bone is attached to the maxilla on the sound side, but is swung forward on the side of the cleft, thus projecting forward far in front of the anterior border of the maxilla of the affected side at the edge of the cleft. In this case the borders of the defect in the lip are nearly perpendicular and nearly parallel. (Infants' Hospital.)

In double hare lip complicated by cleft in the alveolar process there is almost invariably a cleft also in the hard and soft palates. Ordinarily the intermaxillary bone, on which grows the median portion of the upper lip, is tilted upward and forward, being attached only to the nasal septum. (Figs. 202 and 203.) In such cases the antero-posterior length of that part of the nasal septum which lies between the upper lip and the tip of the nose is almost always decreased. (Fig. 202.) Occasionally the intermaxillary bone may, in spite of the cleft on either side, retain its normal position in relation to the rest of the alveolar process. In very rare instances the intermaxillary bone is entirely undeveloped. In such cases the nasal septum is also apt to be imperfect, allowing an extreme flattening of the nose and leaving a single opening into the nasal passages above a median defect in the lip and alveolar process. (Figs. 198, 199, 200, and 201.)

The possibility of true median hare lip has been mentioned.

Age for Operation.—The age of choice for operation in hare lip and cleft palate has always been a matter of much discussion and cannot be regarded as settled. There has undoubtedly been a strong tendency toward earlier operations than were formerly practised. This is especially true of operations upon the palate. Nevertheless, there seems no sufficient reason for advocating operation within the first few days or weeks of life, and there is at present a strong reaction against such procedures. The urgency of parents for an early operation or even their willingness to permit a more or less dangerous operation because of an unsightly deformity, must not influence the surgeon to lose sight of the paramount interest of the child.

Fig. 197.—Double Uncomplicated Hare Lip. In this case the deformity is symmetrical. The alveolar process is not involved. There is no deformity of the nose, which is unusual. The illustration shows the grooving of the lip above the points at which the actual absence of tissue ends. The median tab of skin does not reach down to the normal level of the margin of the lip. This is not a common form of hare lip. (Children's Hospital.)

Hare lip alone without a cleft in the palate or alveolar process can have little if any effect on the general health. Therefore there is no urgency on this account for an early operation. Such children are usually able to nurse. The operation must necessarily interfere with this act for about a fortnight and may for this reason put a stop to breast nursing. When this is a matter of importance to the general health of the child, operative interference may well be postponed till after the child is weaned.

Growth and functional use play a most important part in the correction of any deformity. Growth in the face especially is very rapid in the first few months of life. Therefore it is important that normal functional activity of the muscles of the face be secured as early as possible. In early infancy the parts are very soft and elastic. Healing is usually prompt in spite of the delicacy of the tissues. Operation may be undertaken as soon as the child has a fair start in life. The age of choice may well be between six weeks and three months. In undeveloped children it is well to wait till the physical strength and development correspond to those of a normal child of the age mentioned. It is unreasonable to suppose that correction of a simple hare lip at an earlier age will materially improve the general health. Postponement to a later age will do no harm. It is never well to perform any such operation in hot weather when the tendency to digestive disturbance is great and may be increased by the swallowing of a certain amount of blood.

In cases where the alveolar process is cleft, the age chosen for operation need not differ materially. It may well be a little older, as the shock is a little greater, owing to the added complication.

In cases complicated by cleft palate the latter deformity is of so much greater importance that the age for operation will be discussed in the section upon Cleft Palate.

Under no circumstances should any operation upon the lip or palate be undertaken if the child is apparently too weak to stand the loss of blood, or in the presence of any septic condition in the mouth or nose or any of the adjoining cavities, including the middle ear.

The mortality from operation in properly selected cases is small.

During the time of waiting before operation much can and often should be done toward narrowing the clefts. The sides of the lip may be drawn together

Fig. 198.

Fig. 199.

Figs. 198 and 199.—Front and Side Views of a So-called Median Hare Lip, a rare type of this deformity. Anatomically, the defect is in the median line. Embryologically, there is a double hare lip complicated by an entire absence of the intermaxillary bone and the central part of the lip which grows from it. The lower part of the nasal septum, from which the intermaxillary bone normally springs, is also deficient. This accounts for the extreme flattening of the nose. The breadth of the nose is not abnormal. This case is similar to that represented in Fig. 197, but shows a very much greater absence of tissue, rather than a failure of union.

by strips of adhesive plaster or by strips of *crêpe lisse* fastened in place with collodion. Care must be taken lest food or mucus collect behind the straps and lest the skin become macerated or sore. It may be possible to place the straps properly across the nose rather than directly across the defect in the lip.

Strapping may similarly narrow a gap in the alveolar process. Constantly repeated manual pressure upon the sides of the jaw will do much to narrow a cleft in the palate or alveolar process. In older children or in adults instrumental pressure may be used just as in straightening misplaced teeth.

Operative Treatment.—Certain points are essential in any hare-lip operation. Above all, it is important that any deformity in the line of the alveolar process be corrected. This may be done at a preceding operation, but may usually be done at the time when the lip is sutured. The technique is described in a special section. The other essentials are, first, the restoration of a perfect line where the skin and mucous membrane join; second, the restoration of a lip of sufficient height to cover the teeth properly and presenting below a sufficient thickness of mucous border; third, a lip of proper thickness, especially at the edge of the nostril, to prevent flattening of the floor of the nostril; fourth, the restoration of the nostril to its normal shape by drawing in the ala to its proper position; fifth, the straightening of the septum of the nose.

In determining the exact nature of the operation the details of the deformity in each individual case must be studied carefully. The height and breadth of the cleft, the character of the sides, whether symmetrical, perpendicular, or

Fig. 200.

Fig. 201.

Figs. 200 and 201.—In these illustrations is shown an even more extreme deficiency of tissues than existed in the preceding case. There is, however, in addition, a marked widening of the nose. The cases are otherwise essentially similar. (Original.)

oblique, the thickness of the borders, the amount of deformity of the nose, are all to be observed with care.

The patient should be wrapped in a blanket, the arms and legs being securely fastened, and it may be held upright in the nurse's arms or placed on a table in a semi-reclining position. While the reclining posture offers certain advantages, chiefly in security of position, it has the disadvantage of readily allowing blood to enter the mouth. The experience of the operator will usually determine the position. If the recumbent position is chosen, an assistant must hold the head from above, in order to control the movements and to turn the head in such a way as to minimize the amount of blood escaping into the mouth and pharynx. If the sitting position is preferred, the nurse who is to hold the baby should sit upright in a high chair. She should grasp the sides of the baby's head with both hands, holding it well up and forward with the chin a little elevated. It is desirable that a firm support be placed in the nurse's lap, for nothing hinders the progress of the operation more than to have the child constantly slumping down, with the head receding gradually from the surgeon. A strap fastened around the body of the child will often assist greatly in maintaining the proper position.

The first and one of the most important steps is the free liberation of the flaps. In unilateral cases the edge of the lip on the affected side should be raised and a pair of small blunt-pointed scissors curved on the flat should free the ala and the border of the lip from the underlying bone. This is done with very little bleeding provided the cut is started just where the reflection of the mucous membrane from the bone begins, and provided that the point of the scissors is always kept close to the bone. The edge of the lip beneath the septum and, if displaced, the lower anterior part of the septum itself, are freed in a similar manner. The liberation of the ala and of the borders of the lip is a matter

FIG. 202.

FIG. 203.

FIGS. 202 and 203.—The Ordinary Form of Double Hare Lip and Cleft Palate. The illustrations show the intermaxillary bone projecting forward, with the median portion of the upper lip sticking out as a tab of skin just below the tip of the nose. There is a cleft in the alveolar process on each side of the intermaxillary bone. The nose is somewhat broadened. Note specially the extremely short distance from the tip of the nose to the median portion of the upper lip. This can be seen well in the profile. (Case of Dr. Charles B. G. de Nancrède, Ann Arbor, Mich.)

of the utmost importance in all cases in which there is the slightest broadening of the nostril. A wire stitch may then be passed below and behind the nostril. The needle should enter in the fold just outside the middle of the ala, and should emerge through the septum just inside the nostril of the normal side. It is important that this stitch should be passed deeply into the lip on each side in order to draw the inner surface well together. This stitch when tightened narrows the nostril, brings its lower border upward and forward, gives to the ala its normal shape, and relieves the tension on the stitches in the lip itself. It is later to be fastened with perforated shot after the flaps have been cut and shaped. The only visible scar produced by this stitch is therefore just in the fold between the ala and the cheek. (Fig. 207.)

In the bilateral cases the ala on each side is to be freed in exactly the same way. As yet, in such cases, the median tab of skin below the septum need not be disturbed. In the bilateral cases the wire stitch is to be passed below and behind both nostrils and through the septum, emerging in the fold of the ala at a point corresponding to the point of entrance on the opposite side. With this stitch temporarily tightened the shape of the nose and the width of the defect in the lip will be noticeably altered and improved.

Fig. 204.—Double Hare Lip and Cleft Palate. This is a case of the ordinary type in an older child. It shows the two central incisor teeth growing irregularly from the projecting intermaxillary bone. The nose is asymmetrical and is broadened especially on the patient's right. The gap in the lip is broad. (Case of Dr. Charles B. G. de Nancrède, Ann Arbor, Mich.)

Up to this point bleeding will have been slight and easily controlled by direct pressure in the liberating incisions.

The next step is the shaping of the flaps and refreshing the edges to be united. This will involve more free bleeding, which may be controlled in part by pressure upon the facial artery at the angle of the jaw, or better by grasping the lip outside the defect firmly between the thumb and forefinger. Special forceps have been devised for controlling the bleeding by pressure in the same manner. Langenbeck's *serres-fines* are admirable for this purpose. In cases where skilled assistance is not available the bleeding may be controlled by a temporary ligature passed through the cheek a little above and outside of the corner of the mouth and tied through the corner of the mouth tightly enough to control the included superior coronary artery. The ligature is to be removed at the end of the operation. Up to this point the steps are essentially the same whether the deformity be single or double and no matter how the flaps are to be formed. The method used by many operators in single cases—that of direct union of the refreshed edges of the gap in the form of two flaps of equal length —will be described first.

With the wire stitch temporarily tightened the surgeon should determine exactly the points at the two sides which he wishes to unite in order to form the free border of the lip. These points must be equally distant from the nostril. Otherwise the flaps will be of unequal height. The tension on the wire stitch is then relaxed and the lip is seized between the thumb and forefinger just outside the point selected. A sharp thin-bladed knife is then plunged completely through the lip at the point chosen. The point of the knife should be introduced exactly at the junction of skin and mucous membrane, the blade pointing upward toward the nostril and a trifle away from the mucous membrane into the skin at the sides of the cleft. The knife, being kept always in the skin, should then be carried to a point well beyond the upper edge of the defect, or well into

Fig. 205.

Fig. 206.

Figs. 205 and 206.—Double Hare Lip and Cleft Palate in an Adult. In the illustration on the left the extreme width of the defect in the lip is well shown. This is due to the constant pull of the facial muscles unopposed by any force drawing the sides together. The width is greater than in the preceding case. Comparison with Fig. 203 shows the effect, in widening the gap, of neglect to operate in early life.

In the right-hand illustration the wide cleft from the alveolar process backward through the whole palate is wonderfully well shown. The common malformation of the alæ also stands out clearly. (Case of Dr. Charles B. G. de Nancrède, Ann Arbor, Mich.)

The series of illustrations here given (Figs. 196–206), extending as they do from infancy to adult life, show well the changes occurring with unregulated growth.

the floor of the nostril if the defect extends so far. Care should be taken to cut away enough to secure a sufficient thickness of sound tissue for the new lip. The strip thus freed is left attached at the lower border of the lip. If seized at the tip with hæmostatic forceps it makes a convenient handle with which to control the lip when the stitches are being put in place. The coronary artery may be seized if cut, but it need never be tied. Manual compression of the lip between the thumb and forefinger controls all bleeding readily, and should not be relaxed until the stitches are placed and tied. The opposite side is treated in the same manner. If it is desired to add height to the lip the incisions may be curved with their concavity toward the gap. The stitches are then to be placed in the lip. Silk may be used. Pagenstecher thread is a little better because of its lessened capillarity. Silkworm gut is a little stiff. Horsehair is less stiff, but may be brittle. Catgut or other absorbable sutures are objectionable about the mouth. The author seldom passes the sutures through the entire thickness of the lip, including both skin and mucous membrane. The final appearance of the scar is usually better if the main stitches do not include the skin, but are passed only through the mucous membrane and subcutaneous tissues. If the stitches are thus placed it is well to have them threaded with two curved needles,

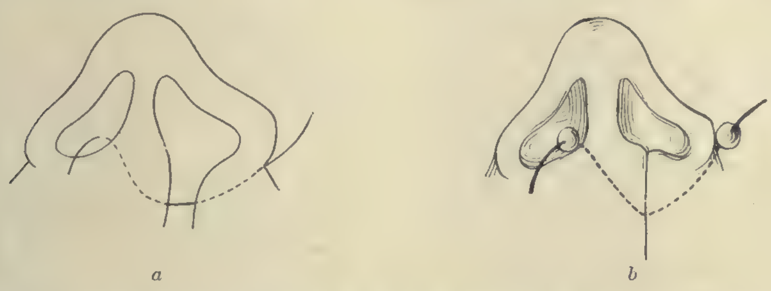

FIG. 207.—Diagram Showing the Manner in which a Silver-wire Stitch may be Passed from the fold outside the ala, under the nostril of the affected side, and out into the nostril of the sound side (*a*). This stitch when fastened with perforated shot brings the ala into normal shape and lifts up the floor of the nostril to its proper position (*b*).

as they may be passed with a little more accuracy from before backward on each side. But very little of the mucous membrane should be included in the stitches. If too much is taken it is apt to curl into the wound and interfere with union. It is important that neither side should curl up or down more than the other, thus exposing a wider red border on one side than on the other. After these stitches—usually three, when the entire width (*i.e.*, height) of the lip is involved—are placed they may be tied on the inside, and the wire stitch may be drawn up and fastened by the shot. It is then necessary to put in three or four fine stitches to unite the edges of the skin accurately. Horsehair is useful here. There remain still the superfluous tabs of mucous membrane which have been retained to assist in holding the flaps and to spare bruising the tissues at the sides by grasping them with forceps. These tabs are cut off obliquely, and the edges of the wound are so united by fine stitches that the mucous border of the lip at the point of suture is abnormally wide because of redundancy. If this is not done the retraction of the lip will form a depression in the mucous border of the lip. If at the time of suture the mucous border is slightly redundant, the contracting scar will probably produce a perfect end result. In trimming off the tabs of mucous membrane it is very important to be sure that no edge of skin is allowed to remain to produce later an unsightly break in the vermilion border.

In those less pronounced cases in which it is necessary to carry the skin incisions into the floor of the nostril, the mucous membrane must still be freed high up in order to give the nostril its proper shape.

In placing the stitches in the lip some surgeons prefer to include only the skin and subcutaneous tissues down to, but not including, the mucous membrane. Such stitches are of course tied externally. If they cut at all they are likely to exaggerate the resulting scar. Hare-lip pins are at the present time very seldom used. They may be helpful in cases in which the gap to be closed is extremely wide.

The surgeon may, if he prefers, start his incisions at the upper edge of the gap and carry them downward to the mucous border, thus freeing the flaps which are to be turned down to form the new red border. In either case it is essential that the flaps swung down be left attached only by the red border. If the lower end of the incision is in the skin, accurate approximation of the two angles is difficult, and, if the stitches cut, a small hole through the lip is likely to be formed. This hole, however, will close by granulation at a later date.

The hemorrhage which occurs when the mucous border is trimmed is usually very free, and, when necessary, is controlled by hæmostatic forceps.

Method of Dressing the Parts.—The line of sutures may be cleansed, dried, and left uncovered. A clot soon protects the wound in fully as satisfactory a manner as any application would. The wound may, however, be dusted with boracic acid or aristol, or may be covered with the compound tincture of benzoin or with any of the various antiseptic varnishes. Frequently a dressing of this sort does as much harm as good by restraining drainage.

Various methods may be used for pressing forward the cheeks and thus relieving to some extent the tension on the sutures. This is generally unnecessary, and anything which brings direct pressure upon the wound or which directly covers the wound is positively harmful. *Crêpe lisse* may be fastened to the cheeks with collodion, but nothing should be allowed to occlude the meshes which lie across the incision. Small pads may be placed against the sides of the cheek under the strap to push the flaps forward and also to hold the strap away from the wound. Two straps of adhesive plaster may be passed diagonally from one side of the cheek to the opposite side of the forehead, crossing each other at the bridge of the nose.

After-care.—After the operation it is often important that the child be kept from crying. The most useful drugs are paregoric and sodium bromide, which should be given in small doses. The hands should be fastened in such a way as to prevent interference with the wound. Care also must be taken that the child does not rub the lip against the pillow or clothing. Aside from this, the only precautions are to prevent contamination by nasal discharges and by food. Nursing is not to be permitted under any circumstances. The child should be fed with a medicine dropper or a spoon, the food being carried well back into the mouth. In case the wound becomes dirty it may be cleaned with sterile water, boracic-acid solution, or hydrogen dioxide.

The time at which the stitches are to be removed must depend on circumstances. Usually the superficial skin sutures may be removed in from five to seven days, the stitches on the inner side of the lip in from eight to ten days, while the wire stitch may often remain as long as a fortnight if it is not cutting the tissues.

If, in any part of the lip, failure of primary union occurs, the surgeon should wait, before attempting a second operation, until the inflammation in the tissues incident to the operation shall have completely subsided. Small defects resulting from failure of immediate union usually close spontaneously in a short time.

Variations in the Technique of the Operation.—Other methods of cutting the flaps should be understood, as they may be useful in the milder cases or in those which are unusually broad or asymmetrical.

Nélaton's Operation.—Nélaton's operation is applicable only in those cases in which there is a very trifling notch at the edge of the lip and in which the

Fig. 208.—Diagram Showing the Operation of Mirault. The diagram on the left shows the manner of making the incisions. The selection of the point A, at the end of the incision on the more perpendicular side, is the important matter. C' represents a point in the normal line of the lip directly below A', which is at or below the centre of the curve in the more oblique side. The distance AC from A to the nearest mucous membrane must equal $A'C'$. AD must equal $A'D$. In refreshing the more oblique side it is well to give a slight prominence at the point A', in order that it may more readily fit into the angle A made by drawing down the flap below the cut AD. Any redundant tissue at what was the apex of the defect, but which is now at the tip of the flap, may be removed as is indicated by the cut which extends to B.

The diagram on the right shows the adjustment of the two sides. As is indicated, a little extra mucous membrane should be left to allow for cicatricial contraction.

nostril is not deformed. Such are rarely met with as congenital defects, but may occur as the result of contractions in the scars of previous operations.

An inverted V-shaped incision is made just above the defect. The flaps thus freed having first been drawn down, the diamond-shaped gap formed may be closed by uniting the two sides. In most instances too great a projection downward of the free border of the lip would result, while the tension on the central stitches would be so great as to cause them to cut and allow a spreading of the middle of the wound. Therefore it is usually far preferable to convert the incision into an inverted Y rather than to attempt completely to reverse the form of the lower flap. The nearer the incision is made to the mucous border the more readily may the flap formed be moulded. The location and form of the cut must therefore be determined by the extent and shape of the gap.

Mirault's Operation.—Mirault's operation is of special value in those instances in which the sides of the gap are not symmetrical, or in which they diverge widely. The purpose of the operation is to secure a proper height of lip by turning a flap from the edge of the more vertical side under the refreshed edge of the opposite side. (Fig. 208.) The lip on the more vertical side should be transfixed at a point a little above the mucous border. The distance of this point from the border of the lip (*AC*) should be governed by the obliquity

Fig. 209.—Diagram Showing the Operation of Giraldès. An incision, *AC*, is made from the upper part of the defect directly outward in the curve below the ala. A flap from the opposite side, with its pedicle directly beneath the septum, is then turned up into the space made by the first incision. Thus the lip outside the defect is given additional height, a gain varying with the width of the flap taken from the opposite side. The lower portions of the refreshed sides of the gap are then united. The length of the flap *A′C′* must equal the length of the incision *AC*. The distance through which the outer border of the cleft is to be refreshed (*AB*) is determined by the raw surface left on the opposite side after the flap is turned up. The point *B*, however, should be as far above the normal level of the lip border as the point *A′* is distant from the margin of the cleft; that is, *B* is depressed by exactly the width of the flap at *A′*. At the mucous border a little redundant tissue should be left to allow for cicatricial contraction.

of the opposite side (*A′C′*). The distance of the point from the apex of the defect (*AD*) should equal the distance from the apex of the defect to a point somewhat below the centre of the curve in the defect on the opposite side (*A′D′*). The knife is then made to cut upward to a point above the apex of the defect.

The opposite side of the cleft is next to be refreshed. No mucous membrane is to be left, but as much skin as is possible should be saved. It may aid in

Fig. 210.—Diagrams Showing the Operation of Simon. The surgeon determines how much he wishes to add to the height of the lip. A cut is then made (see left-hand figure) downward on each side of the defect. The incision on one side is made close to the mucous membrane (incision to *A*). On the other side, starting close to the mucous membrane, it is carried downward and ends as far away from the mucous border as it is desired to add to the height of the lip (incision to *A′*). The lengths of these two incisions must be equal. From the end of the first incision a second is made upward and outward into the lip at right angles to the first (*AC*). The length of this incision should equal the distance from *A′* to the mucous border. The point *B* below the incision may then be depressed. Obviously the sides of the gap thus made (*CA* and *CB*) are equal in length. At this same distance above *A′* an incision is made across the flap on the opposite side (incision *C′B′*). The flap is thus squared at the end and is given such a shape as to make it fit into the gap on the opposite side of the defect. The right-hand figure shows the two sides of the gap ready to be united by sutures.

approximating the flaps if the refreshed edge projects slightly at *A′*. It is important that the flap which is turned down should be ample. (Fig. 204.)

Giraldès' Operation.—Giraldès' operation is analogous to that of Mirault, but the incision by which one flap is superimposed upon the other is made just below the nostril instead of near the lower part of the lip. Instead of the mucous membrane being excised along the more oblique side, it is left attached above and is turned up to make the floor of the nostril. On the opposite side a transverse incision is made to form a space into which this flap may be introduced. (Fig. 209.)

There are very serious objections to the operation. It is applicable only in those cases in which the cleft extends up to the nostril, which is then always widened and flattened. The operation not only does nothing to narrow the nostril to its normal shape, but leaves it provided with a lower border of red mucous membrane instead of skin, unless the flap is narrowed by excision of the mucous edge.

Simon's Operation.—Simon's operation is somewhat similar to that of Mirault in that a piece from one side of the cleft is made to fit under a gap in the

FIG. 211.—Diagrams Showing the Operation of Hagedorn. The mucous borders of the defect are excised in exactly the same manner as in the ordinary operation. The lengths of the incisions (*D* and *D'*) are equal. From the lower end of one incision a cut (*C'B'*) is made upward into the lip at right angles to the border of the defect at this point. The length of this cut should equal the amount of height to be added to the lip. On the opposite side, at this same distance above the lower end of the primary incision, a curving incision (*BA*) is carried downward and outward into the lip. The length of the cut *BA* must equal the distance *BC*, and also they are both equal to the length of the cut *B'C'*. Thus a gap may be made on one side into which a flap from the opposite side is fitted. The completed work is shown in the right-hand figure.

opposite side. The incisions made, however, are angular instead of curved. The flap which is turned down is, moreover, broad at the tip instead of being pointed. (Fig. 210.)

Hagedorn's Operation.—Hagedorn's operation is essentially like that of Simon. The mucous border of the cleft is excised at the upper part. At the lower part there are left attached short tabs of mucous membrane which may be turned down and joined. Low down on the median side of the cleft a short incision is carried from the base of the flap of mucous membrane upward and outward into the skin. At a slightly higher level, on the opposite or lateral side of the cleft, an incision of the same length is made running outward and downward upon the skin. If the lip is drawn down, a slight gap in the side is thus formed and into it the projecting point of skin on the opposite side may be fitted. There is thus gained a little extra height which could otherwise be secured only by increasing the lateral tension. A study of the technique will show that these lateral incisions may be made if, in the course of the ordinary operation, the height of the lip proves insufficient. (Fig. 211.) But it is very easy to add too much to the height of the lip.

Koenig's Operation.—Koenig, by making incisions on each side outward and slightly downward, a little above and parallel with the red border, renders the lower edges more mobile, so that they may be stretched a little more than if still fastened to the lip above. (Fig. 212.) The gain is accomplished at the

FIG. 212.—Diagrams Showing the Operation of Koenig. In cases in which the lower parts of the sides of the gap diverge widely, lateral incisions made nearly parallel with the lip border allow the flaps thus made to be moved with more freedom than would otherwise be possible. The procedure is one of expediency only.

expense of a disfiguring and decidedly larger scar. The chance of non-union of the lower border is considerable, and in case primary union fails the result is likely to be extremely bad. The procedure may be practised in the course of the ordinary operation, but had better be reserved for cases in which a secondary operation may be necessary at the border of the lip.

DOUBLE HARE-LIP OPERATIONS.

The manner of operating in cases of double hare lip must depend upon the symmetry or asymmetry of the sides of the cleft and on the size and shape of the central piece of skin located just below the septum.

In the description of these operations it is assumed that any displacement of the intermaxillary bone has been corrected, as about to be described in the section on Preliminary Operation upon the Displaced Intermaxillary Bone. In all operations the alæ are to be freed on both sides, and the wire stitch is to be passed below both nostrils as described in the unilateral operations.

In those rare cases in which the central piece of skin extends downward for the full height of the lip the operation may be simply the performance of the operation for unilateral hare lip on each side. These operations may be done at one or at two sittings. In the not uncommon instances in which there is a complete cleft on one side and a very small cleft on the other it may be wise to operate upon the more marked side first, and then to wait for at least six or eight weeks before operating upon the other side, in order that adaptive changes in the lip, the result of the new conditions, may become well established. In this way a more perfect final result may be obtained than by the performance of both operations at one sitting.

In the type of double hare lip most frequently seen the clefts are approximately equal and the central portion of skin is insufficient to give proper height to the lip. In other words, it is usually necessary so to plan the flaps of skin, one from each side, that they shall unite below the central tab.

In cases in which the outer sides of the two clefts are relatively perpendicular and the median piece of skin narrow, the operation is merely an adaptation of that performed in single hare lip. The median tab of skin is to be freed and the mucous membrane is to be dissected away from its sides by a V-shaped incision. The two lateral flaps are then to be pared and united exactly as in the unilateral operation, except that the median tab is to be sutured between them at the upper part of the wound, which will, when united, have a Y shape. (Fig. 213.)

Much more commonly, however, the divergence of the two lateral portions of the lip is too great to allow of their immediate union without undue tension and narrowing of the mouth. In these cases flaps must be formed from the sides in such a manner that they may be turned under the median portion. This portion should be freed and trimmed to a rectangular shape. (Fig. 214.) Next, from each side a flap of skin and mucous membrane is cut from the lateral

FIG. 213.

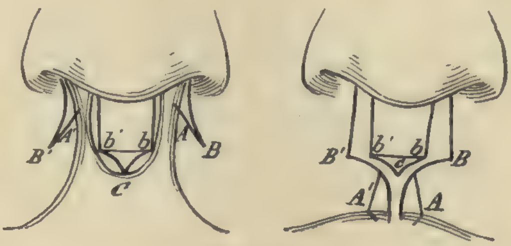

FIG. 214.

FIG. 213.—Diagram Showing the Operation for Double Hare Lip. The mucous borders of the gap are excised and united in a Y shape. The point of the central tab of skin does not reach to the newly formed mucous border when A and A' are approximated.

FIG. 214.—Diagrams Showing the Operation for Double Hare Lip. The incisions on the sides of the median tab (to b and b') must be equal and of the same length as the incisions made into each side of the lip (to B and B'). These latter incisions must end at points one-half as far from the mucous border as the median tab is wide; that is, the distances from B to the mucous border and from B' to the mucous border must, when added together, equal the distance from b to b'. In order to secure accurate apposition of the three flaps at the point C two alternatives are possible. Either the incision between b and b' may be made straight, or else it may be curved down, in two symmetrical halves, to a point at C. If the lower end of the tab is cut straight off, the lateral flaps must be trimmed squarely by the cuts A and A'. Their ends thus are approximated squarely, and the line of union is that of a letter T. If the lower end of the median tab is cut down to a point at the middle, the lateral flaps may be drawn down in a curve and united below the median point, thus making the line of union have a Y shape.

borders of the cleft, the free end of the flap being above, the attached end below. These lateral flaps are then turned down and united to the median piece above and to each other in the median line below.

The length of the lateral incision should equal the height of the central flap. The distance of the lower ends of the incisions from the mucous border must be such that, added to the central portion, it will make the restored lip of proper height. The greater the height of the central flap the narrower need the two lateral flaps be. They should, however, practically always include skin as well as mucous membrane.

It is plain from the diagram (Fig. 214) that special pains must be taken to perfect the apposition at the point where the three flaps meet (C). The difficulty in securing satisfactory apposition may be met either by trimming off squarely the ends of the two lateral flaps (incisions A, A') or by making the lower border of the median flap pointed instead of straight (C).

Hagedorn modifies the operation somewhat by changing a little the direction of the cuts. The median portion is freed and the red border excised as in the previous operation. The mucous membrane is excised from the upper part of the outer sides of the cleft by an incision made close to the edge of the skin. Incisions are then to be made downward and outward on each side above but parallel with the border of the mucous membrane below. The height at which

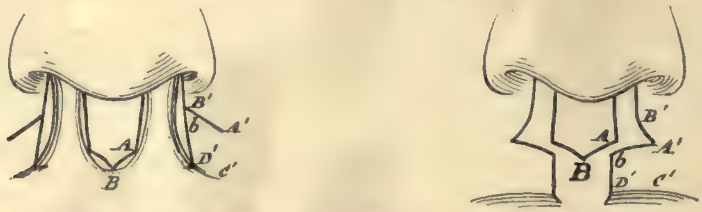

Fig. 215.—Diagrams Showing the Operation of Hagedorn for Double Hare Lip. The borders of the central tab are refreshed; the median part of the lower border being made as pointed as possible. The mucous borders of the lip on both sides of the defect are excised at the upper part only (to D'). Secondary incisions ($B'A'$) are then made downward and outward into the lips on each side of the defect. These incisions should be parallel with the curving lip border between D' and C'. The distance from the nostril to A' should equal the height of the side of the median tab (to A). The length of the cut $B'A'$ should be one-half the width of the lower border of the median tab BA.

these incisions are made varies with the width (height) of the median flap. They should end approximately at the level of the end of the perpendicular incisions at the sides of the median flap (A, A'). The length of the incisions should be half the width of the median flap. (Fig. 215.)

In the application of the stitches, the dressing, and the after-care of the double hare-lip operations the same rules hold good as in the unilateral operations. The same precautions are necessary here as in all hare-lip operations to prevent undue contraction of the border of mucous membrane.

Preliminary Operation upon the Displaced Intermaxillary Bone.

Displacement of the intermaxillary bone must invariably be corrected before the defect in the lip is repaired. It is usually possible, however, to correct both deformities at the same operation.

When the bone is not attached to the alveolar process on either side it must always be forced back into its place between the alveolar processes. The intermaxillary bone should never be excised, no matter how great its displacement, except under the most extraordinary conditions. In cases in which replacement of the bone presents extraordinary difficulties, a part of the bone may be removed subperiosteally by means of a curette inserted through a small incision. Although in very young babies the supporting septum can sometimes be broken and the intermaxillary bone be thus forced back into position without any cutting, it is usually preferable to cut the septum. This should be done with the least possible injury to the mucous membrane. A longitudinal cut should be made through the mucous membrane, at the lower free edge of the septum behind the intermaxillary bone, long enough to allow the introduction of a periosteal elevator on each side, for the purpose of separating the mucous membrane from the cartilage in an upward direction for a distance of about half an inch. (Figs. 216 and 219.) Through this cut the blades of a pair of blunt-pointed scissors may be introduced, one on each side of the cartilage, which may be cut through as far as the mucous membrane has been raised. Then the intermaxillary bone can readily be forced back into place. It is rarely necessary to cut out an inverted V-shaped wedge. The cut edges slide by each other readily, but the operation is more perfect if a piece is excised. (Figs. 217 and 220.)

It is plain that the higher the incision through the septum is carried, the higher is the pivot from which the intermaxillary bone is pushed back. The

Fig. 216.

Fig. 217.

Fig. 218.

Figs. 216, 217, and 218.—Diagrams Showing the Manner of Dealing with a Projecting Intermaxillary Bone.

Fig. 216 shows the intermaxillary bone projecting upward and forward at the tip of the nose, with a small bit of skin representing the middle of the upper lip lying on it. The curved dotted lines indicate the area of periosteum at the sides of the nasal septum which must be separated to permit the incision of the septum along the dotted perpendicular line.

Fig. 217 shows the intermaxillary bone pushed back into its position. The dotted lines indicate how the cut portions of the septum slide by each other, or indicate how large a V-shaped piece should be excised from the septum.

Fig. 218 shows the flattening of the nose incident to carrying back the intermaxillary bone. The distance from the lip to the tip of the nose remains short. Note also the undershot appearance of the jaw. Care is necessary to guard against too long an upper lip.

higher this point is and the longer the radius of the arc through which the bone is turned, the less is the bending in of the inferior part.

It is impossible in this procedure to prevent the edge of the intermaxillary bone from tilting slightly backward at the bottom when it is brought into its new position. This tends to cause a flattening of the upper lip. As the teeth develop, and especially with the coming of the second teeth, this loss of prominence of the middle of the upper lip decreases. Regulation of the teeth by dental appliances helps to correct the trouble. In neglected cases where the tilting in of the border has been extreme the teeth may grow directly backward above the tongue. The irregularity of the teeth is of course increased by any damage done to them during the operation.

The antero-posterior length of that part of the septum which is situated between the upper lip and the tip of the nose is always decreased in this deformity. Thus the nose also is much flattened when the intermaxillary is pushed back into place. Growth, however, here also helps to produce a much better appearance. Even under the worst conditions the loss of prominence of the upper jaw, which gives in profile an undershot appearance, and the flattening of the nose are in no way to be compared with the deformity resulting from an unnecessary excision of the projecting intermaxillary bone. (Figs. 217 and 218.)

In the second class of cases, where the intermaxillary bone is separated on one side only, it must be forcibly swung backward and inward till its free edge rests against the edge of the alveolar process. Except in young babies, it is difficult to break the alveolar process without first cutting partly through it. Pressure with the thumb directly against the projecting bone, while the head is

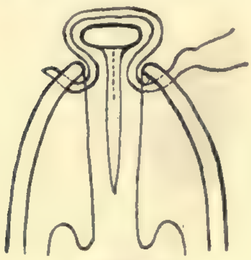

FIG. 219.

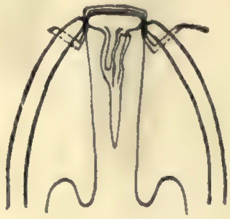

FIG. 220.

FIG. 221.

FIGS. 219, 220, and 221.—Diagrams Showing further Details of the Operation upon the Intermaxillary Bone.

FIG. 219 shows the projection of the intermaxillary bone, supported only by the nasal septum, far in front of the alveolar processes at the sides. The place at which the mucous membrane of the septum is to be cut and separated is indicated by the dotted line. The manner in which the silver-wire sutures are to be passed to pull back the intermaxillary bone is also indicated.

FIG. 220 shows the intermaxillary bone forced back into its proper position between the alveolar processes, and held there by the tightened silver-wire sutures. The manner in which the cut portions of the septum slide by each other is also indicated.

FIG. 221 shows, as seen from in front, the silver-wire sutures tightened in place holding back the intermaxillary bone.

grasped firmly with the other hand, may break the bone enough to allow it to come into place. If this is impossible, a stout narrow-bladed knife should be inserted vertically into the alveolar process high up where it meets the mucous membrane of the lip. The exact spot should be chosen carefully. The knife should be inserted between the points at which teeth appear likely to come, and as nearly as possible at a point corresponding to the cleft in the alveolar process on the opposite side. The point chosen should certainly never be any nearer the median line than this; it may be a little outside it. (Fig. 222.) By moving the handle of the knife up and down a considerable amount of bone may be cut through, while the incision through the periosteum will remain comparatively small. Then with firm pressure by the thumb the bone can be broken back. (Fig. 223.) Springing it back into place is not enough. It must be broken so that it stays in its position with but slight pressure. Forceps may be used to force the projecting bone into position, but the pressure is likely to injure and squeeze out the rudimentary teeth.

The bone is held in its position best by a silver-wire stitch. If this is passed in the ordinary manner, uniting directly the edges of the cleft, it is very liable to cut out, and at best, by pulling laterally, it works at a great disadvantage in preventing the bone from springing forward. It is best to pass it as a mattress suture from front to back through the alveolar process at the side, a spot suitable for this being chosen between two rudimentary teeth, and the points of perforation being placed one a little above the other. The two wires are then to be brought forward through the cleft. When the deformity is unilateral, the wires are to be passed again from front to back through the projecting bone. This can then be pushed into place, and the wires twisted within the mouth behind the bone which formerly projected. Thus it is easily maintained in its new position. (Figs. 222, 223, and 224.) In this way the pull of the wire is backward much more than inward. The tendency of the bone is to project

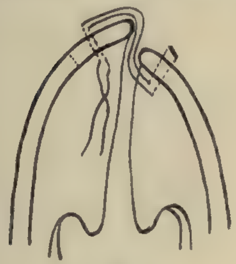

FIG. 222.

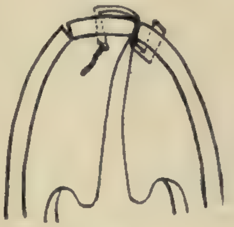

FIG. 223.

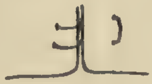

FIG. 224.

FIGS. 222, 223, and 224.—Diagrams Showing the Steps in the Operation upon the Intermaxillary Bone in a unilateral cleft.

FIG. 222 shows the swinging forward and outward of the free edge of the intermaxillary bone in single hare lip and cleft palate. The manner in which the silver-wire suture should be passed to pull the bone backward is indicated. The point at which the alveolar process should be cut through to facilitate fracture is indicated by the dotted line on the left.

FIG. 223 shows the bone broken back into its place and held by the tightened wire suture.

FIG. 224 shows the tightened wire suture as seen from in front.

forward. It is prevented from moving outward by the tissues which hold it, like a hinge, along the line of fracture.

In the case of a bilateral cleft of the alveolar process, if there is much tendency of the intermaxillary bone to spring forward, a wire stitch can be passed in a similar manner from front to back through the alveolar process on one side. The two ends may then be drawn out through the cleft, passed in front of the intermaxillary bone, directly under the central tab of skin, drawn back through the cleft on the other side, and passed from back to front through the alveolar process on the opposite side, to be twisted together in front after being drawn tightly across the intermaxillary while it is pushed into its proper place. (Figs. 219, 220, and 221.)

The edges of the mucous membrane on either side of the cleft had better be excised. This is not essential, but it hastens union if they are brought into good contact. If, however, they are simply apposed, union usually occurs, after a time, with the changes due to the eruption of the teeth. If good apposition cannot be secured, refreshing the edges will be useless. The wire stitch in the alveolar process may well be left in place for about six weeks, unless it causes irritation.

Kroenlein has devised an ingenious method of accomplishing with one stitch the purposes of the wire passed behind the alæ and below the nostrils, and of that which holds back the projecting intermaxillary bone; both of which procedures have already been described—the former in the section which treats of the hare-lip operation, and the latter on page 518. A wire is passed through the cheek, from outside inward, a short distance outside the ala. It is then carried forward through the gap in the lip on the same side, is passed in front of the projecting intermaxillary bone below the central portion of the lip, backward through the gap in the lip on the opposite side, and from within outward at a point corresponding to the original point of entrance. The stitch is to be fastened with perforated shot, beneath which, as an additional safeguard against cutting, may be placed a small perforated metal or celluloid plate.

FIG. 225.—Procedure of Duplay for Sliding Backward and Inward a Projecting Intermaxillary Bone too firmly Ossified to be Swung into Place. The dotted line indicates the incision in the palatal plate. The arrow indicates the direction in which the bone is to be slid. Resulting irregularities in the teeth may be corrected later.

The objection to Kroenlein's method is that the pull backward on the projecting intermaxillary bone is often not sufficiently firm. Furthermore, the stitch must be removed in order to prevent the development of a scar upon the cheek before the bone becomes firmly fixed in its new position.

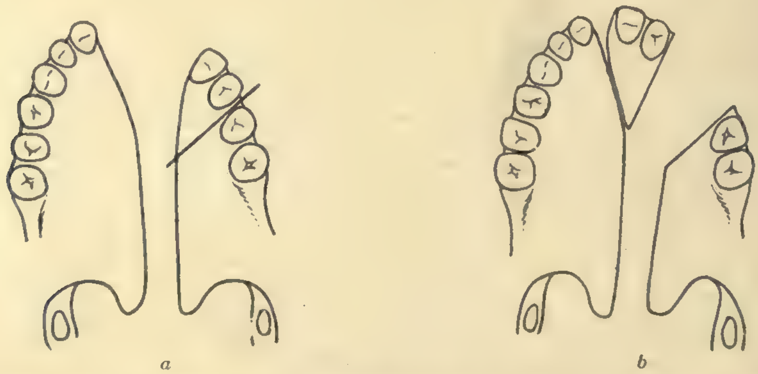

FIG. 226.—Wyeth's Operation. In *a* is shown the line of the incision by which a portion of the alveolar process below the ala and just outside the cleft may be separated from the rest of the palate and alveolar process.

In *b* is shown the separated piece of bone drawn forward and inward into contact with the alveolar process on the other side of the cleft. A gap is left at the side instead of at the front.

In cases in which, because of the patient's age, the bones are unusually solid, it may be necessary to cut through the palatal plate as well as through the alveolar process, in order to slide the projecting intermaxillary bone diagonally backward and inward into place rather than to swing it into place. Any

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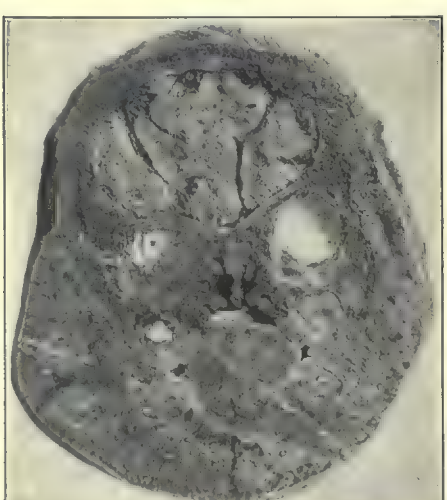
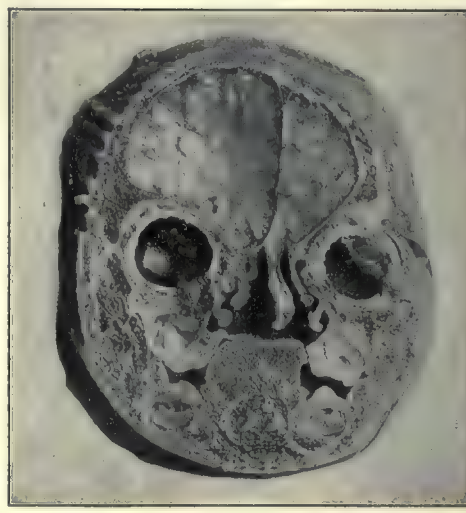


III

IV



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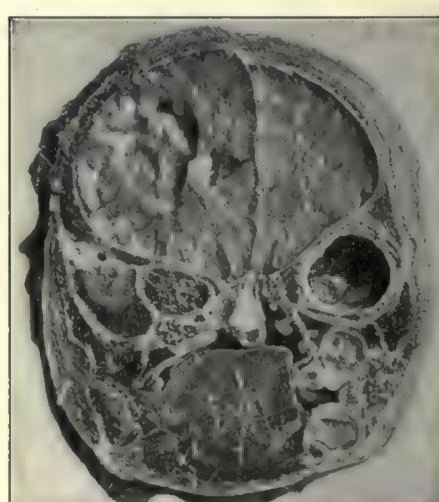


VI

FROZEN SECTIONS OF TWO CASES OF CLEFT PALATE

EXPLANATION OF PLATE B.

FROZEN SECTIONS OF TWO CASES OF CLEFT PALATE.

(Original.)

Both patients died within a few days after birth.

In the left-hand column are shown the face (Fig. 1) and vertical transverse sections of the head (Figs. 2 and 3) of an infant in whom there was entire absence of the intermaxillary bone and anterior part of the nasal septum, associated with extreme flattening of the nose.

Fig. 1 shows well the appearances of the face. It will be noticed that the upper lip projects in front of the lower lip.

Fig. 2 is the section behind Fig. 1 and is made through the lower incisor teeth and about through the middle of the eyes. The tip of the tongue is cut off. The large turbinate bones show well. The very small amount of palatal tissue is strikingly shown. The septum of the nose does not reach as low as the normal level of the palate. The seemingly increased breadth between the upper alveolar processes, as compared with that between the lower processes, is due to the fact that the upper jaw projects in front of the lower. Therefore the cut passes through a different portion of the curve in the jaw above as compared with the corresponding portion in the jaw below.

Fig. 3 is the section behind Fig. 2, and is made through the posterior parts of the eyes. The alvolar processes of the upper jaw are the same distance apart as those of the lower jaw, because in this plane the cut is behind the curving part of the jaw. The very small amount of palatal tissue is evident. The proximity of the rudimentary upper teeth and the eyes shows plainly the absence of any open antrum.

In the right-hand column, Figs. 4, 5, 6, are shown the sections of another child's head in which the intermaxillary bone is present, but not displaced, being separated by a groove from the alveolar processes on each side.

Fig. 4 shows a section made through the lower incisor teeth below, while, above, it passes in front of one and through the other eye. Here again the apparent increase in the width of the upper jaws, as compared with that of the lower jaw, is due to the fact that the cut passes through a different part of the curve in the projecting upper jaw as compared with the corresponding part of the lower jaw. The well-developed turbinate bones, the deviated septum, and the small amount of palatal tissue are clearly shown.

Fig. 5 shows the section behind Fig. 4. It passes through both eyes. The upper and lower jaws are of the same breadth because the cut is made behind the curving portions of the jaw. The close proximity of the teeth to the eye, and the absence of any open antral space, are shown plainly. The amount of palatal tissue is insignificant.

Fig. 6 shows the section behind Fig. 5. On the right side the cut is through the eye. On the other side it passes behind the eye and behind the teeth. On the right the proximity of the eye to the teeth is very marked. The thin, insufficient soft palate is seen on each side, on the right being somewhat curled up on itself.

Art. 57

such cutting of the bone should be done subperiosteally as far as is possible. (Fig. 225.)

In order to correct the flattening of the nostril on the side of the cleft, Wyeth (*Medical Record,* New York, 1893, Vol. 43, p. 769) has advocated a procedure exactly the reverse of that of Duplay. A part of the superior maxillary bone on the affected side is advanced. This may be done by cutting through the alveolar process between two teeth, and then completing the fracture by traction upon a cord or tape inserted into the incision. In this manner there is less likelihood of doing harm to the teeth than by prying forward the loosened piece of bone with a chisel. (Fig. 226.) The advantage of the operation is that a bony support is brought beneath the floor of the nostril, thus overcoming the depression on the affected side, which is often so hard to overcome.

II. CLEFT PALATE.

General Remarks.—Cleft palate causes much greater disturbance of nutrition than does hare lip. Cleft palate and double hare lip interfere so seriously with nutrition and the general health as very commonly to be fatal within a year or two, unless one or the other condition is relieved by operation. The anatomical conditions are well shown in Plate B.

The surgeon must decide at what age uncomplicated cleft palate is to be operated on, and, in the cases complicated with hare lip, which deformity is to be corrected first. The influence of age upon the risk to life, upon the chances of success in obtaining union, and upon the gain in health which may be expected to result from a successful closure of the cleft, must all affect the decision. It should be said, regarding the risk to life, that in the experience of most operators the younger the patient the greater the danger. Some maintain, however, that in the first few days the nutrition of the child is at its best, not having been interfered with in any way by the deformity in the mouth. In some cases this is true. In many, however, the deformity seems but a part of a general condition of poor nutrition during intra-uterine life. In such subjects the danger in operating is certainly great. In those well nourished at first, careful nursing and proper feeding will generally maintain their good condition.

Age does not make a great difference in the chances of successful union. Of course, the co-operation of the patient is a help. Formerly many surgeons preferred to wait for about seven years. It was argued that then the child is old enough to co-operate in the after-care and, if desired, in the use of a temporary plate attached to the molar teeth, which device will guard the line of union from the action of the tongue. This, at the present time, is usually regarded as unnecessary. Few children, if placed under the charge of a nurse or in a hospital, cannot be made tractable in a few days. Babies can and should be kept quiet during convalescence by drugs, just as in hare-lip operations.

The benefit to the general health resulting from the closure of a cleft palate is open to no question.

As regards speech, it is well to have the operation performed if possible before the child is fifteen months old. After that age patient and persistent training will be required to perfect the voice. A successful closure of a wide cleft even before that age may still leave a palate at first insufficient completely to cut off the naso-pharynx.

The nasal cavities develop in a much more nearly normal manner after closure of the cleft.

While it is impossible to lay down any definite rules, it is best to wait at least six months even in the most favorable cases. Waiting for from ten to fifteen months will do no harm. The season of the year will influence the decision somewhat. In less favorable cases it may be well to wait till the child is two years old or over. A strong argument for delay is the decided tendency of the

Fig. 227.

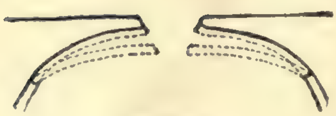


Fig. 228.

Fig. 229.

Figs. 227, 228, and 229.—Diagrams Showing the Difference in the Ease of Approximating the Flaps in the operation in a high-arched and a low-arched palate.

Fig. 227 shows the manner in which the flaps freed from the hard palate meet readily by dropping toward the tongue when the vault of the palate is high and the borders of the gap are more nearly vertical.

Fig. 228 shows the difference in this respect when the vault of the palate is low and the borders of the gap are more nearly horizontal.

Fig. 229 shows how the flaps must actually be drawn in from the sides in order to meet when the vault of the palate is low. A gap in the mucous membrane (*AA'*) is shown on each side.

cleft to narrow with growth, especially if very wide at first. The narrowing of the cleft in the palate is often very marked after union of the lip and alveolar process. In some instances the width of the cleft becomes not actually but only relatively narrower; that is, the growth of the two sides gives more tissue with which to fill the median defect. While growth broadens the tissue at the sides, the tongue may tend to tilt the free edges upward, making a higher vault.

Before deciding upon operation one must estimate carefully whether the tissues are sufficient to allow the formation of satisfactory flaps. The width of the cleft is most important; the length makes little difference. It is generally as difficult to secure union in a cleft of the soft palate alone as in a complete cleft throughout the hard and soft palates. The more nearly vertical the sides of the cleft the greater the ease in approximating the edges of the flaps; the more nearly horizontal the sides the harder it is to get approximation. (Figs. 227, 228, and 229.) In some cases the tissues at the sides of the cleft are so deficient as to preclude a reasonable chance of successful closure by ordinary methods.

The thorough removal of the tonsils before operation gives much freedom to the flaps, and should always be done if there is any tonsillar hypertrophy. No operation should be undertaken on the palate unless the child is in good physical condition. The hemorrhage and shock are always considerable. The convalescence is hindered by the difficulty in feeding. In babies the digestion is often upset by the blood and mucus which are swallowed during the operation. No operation should be undertaken if there is any local disease. Any inflammation of the mucous membrane of the nose or mouth should be cured by scrupulous cleanliness and care before operation is considered. In cases in which there is purulent otitis media, a not uncommon condition, everything should be done to cure this condition before operation; otherwise there is great likelihood of failure as a result of immediate pyogenic infection of the wound through the Eustachian tube.

In cases in which delay is necessary, something may be accomplished, by pressure against the alveolar processes, toward narrowing the cleft. In older children apparatus fastened to the teeth may be used for this purpose.

The immediate danger to life, in cases suitable for operation, is not great. The shock after operation is often considerable, but is very seldom fatal. A much greater risk, especially in very young children and in those not in good physical condition, lies in the debilitating after-effects of the operation. Thus, a baby who is thin, who has been gaining weight but slowly, and who is liable to digestive upsets, should not be subjected to the inevitable digestive disturbance, often serious and possibly in the end fatal, following operation. In older children the debility after operation may predispose to contagious disease. Thus, a death may be directly attributable to the lack of resisting power resulting from the operation.

Historical Sketch.—Lemonnier, in 1767, repaired a cleft in the soft palate. This was the first operation of the sort performed. About forty years later three surgeons, working independently, laid the foundations for the operations of to-day. von Graefe (*Journal der Chirurgie und Augenheilkunde*, Berlin, 1820), in 1816, in Germany; Roux (*Arch. g'n. de Méd.*, Paris, 1825), in 1819, in France; and Warren (*American Journal of the Medical Sciences*, 1826), in 1820, in America, performed their first operations. In 1845, Dieffenbach ("Die operative Chir.," Leipsic, 1845) added to the technique the lateral incisions, a step soon followed up by Ferguson (Medico-Chirurgical Transactions, Vol. XXVIII., p. 273; *Medical Times*, Mar. 6th, 1847; *Lancet*, June 25th, 1864), who proposed cutting the palatal muscles in order to maintain the parts at rest. In 1873, Ferguson suggested an osteotomy of the palatal plates, thus making it possible to approximate the sides of the hard palate throughout their entire thickness instead of merely the muco-periosteal portions. Billroth, in 1889 (*Wiener klin. Wochenschrift*, 1889, No. 12), proposed osteotomy of the hamular process.

At first, there was no thought of operating in very early life. Later, the feeling in favor of earlier operations arose, but received numerous discouraging setbacks. Langenbeck, in spite of his belief that operation on the palate in early childhood was desirable, found the difficulties so great that he advised postponement to the age of from twelve to fifteen years. Later, he lowered this age to eight years in case the soft palate alone was cleft. Billroth likewise was disappointed in the results which he obtained from early operation. After 1863 numerous surgeons undertook operation in early infancy, but with such poor results that the opinion of Trélat, that operation was not permissible before the seventh year, received almost general acceptance. As this view became more firmly established the advantages of the artificial palate loomed up more prominently. To Wolff largely belongs the credit of establishing the advantages of early operation. He performed the operation in stages, using the utmost care in preventing hemorrhage. In this country Brophy greatly stimulated the movement toward early operation by his advocacy of the wisdom of operating within the first few weeks of life. In England Lane has been a strong advocate of operating at a very early period, that is, within the first few days of life.

In spite of the experience of these men the view generally taken by other surgeons of wide experience is that the risks of very early operation are too great to be taken lightly.

Technique of the Operation.—In operations on the palate the Rose position is greatly to be preferred to any other. The splendid view of the field and the diminished risk of inhaling and swallowing blood counteract fully the disadvantage of the increased bleeding due to the lowered position of the head—a disadvantage largely overcome by raising the shoulders and upper part of the body. The only precaution to be taken is to have the head tilted back sufficiently to allow the blood to escape freely from the nostrils. A gag should be chosen which grasps the alveolar processes firmly, but does not project into the mouth and so cover part of the field of operation. Occasionally a gag which opens the mouth too widely will stop respiration. A stitch should always be put through the tongue in the median line at the outset to draw it forward and control it. Combined gags and tongue depressors may prove in some cases very satisfactory, in others very annoying. They are never essential.

If ether be the anæsthetic selected, care must be taken lest any be allowed to drop into the mouth. Ether vapor may be pumped through a tube into the nose or pharynx, but if this is done the greatest care must be exercised lest it become too concentrated and irritating. There is a considerable risk of post-operative pneumonia. Excessive secretion of mucus may be counteracted somewhat by a hypodermic injection of atropine, given about half an hour before the operation.

At the present time the distinction made between the operation upon the hard palate—uranoplasty—and the operation upon the soft palate—staphylorrhaphy—is no longer one of practical importance. As a rule, the simpler the method of operation chosen the better.

Three conditions are essential to operative success; first, broadly denuded surfaces; second, accurate apposition; third, entire absence of tension in the line of union.

(1) The first condition may be obtained by so cutting away the border of

the cleft as to remove as much tissue from the upper nasal surface as from the lower oral surface of the edge of the cleft. The cut should be made with a sharp narrow-bladed knife or bistoury. It is usually easiest to introduce the knife directly through the uvula well toward its tip and to cut forward to the anterior angle of the cleft. The knife, once introduced, should not be withdrawn till the cut on that side is completed. Care should be taken to cut away the border in a continuous strip. It is more economical of tissue and gives a more even surface to cut away a strip of width sufficient to remain whole than to cut away a strip so narrow that it may tear and necessitate repeated incisions to insure a properly denuded edge. In the first cut it is easy to see just what is being done. Afterward, as blood and mucus accumulate, it is extremely difficult to tell exactly how fully the edges of the cleft have been denuded. It is of the utmost importance that no spot be left with the edges not completely refreshed. The anterior angle of the cleft is a point at which this is particularly liable to be overlooked. In each half of the uvula it is often possible to leave attached a small piece of the strip which has been freed. These tabs may then be turned back on each side and joined in such a manner as slightly to elongate the united uvula. The tissue is so yielding and elastic that the folding back of these little tabs does not interfere with their circulation. Fine sharp scissors may be used in denuding the edges, especially if the knife has not removed enough mucous membrane in any one spot.

(2) Accuracy of apposition, the second condition, cannot be obtained unless the utmost care is taken that the sutures be passed at regular intervals, always equally distant from the cleft and at exactly corresponding points on the two sides. There is little difficulty in placing the sutures if, on each side, they are passed from the oral to the nasal side. It is often difficult to pass them in the opposite direction. The chance of their coming out at irregular points is considerable. Many more or less elaborate instruments have been devised for passing sutures in cleft-palate operations. A favorite method of passing the sutures is by means of a cleft-palate needle provided with a handle and shaped like an aneurism needle, by means of which a loop may be passed through the cleft on one side and then seized and held while the needle is withdrawn. The suture passed through the opposite side may be engaged in this loop and thus drawn through both sides. Other more elaborate needles have been devised. None of these instruments is really necessary. Several fine, small, full-curved, round needles without a cutting edge are best. They may be threaded with as stout Pagenstecher thread as they can carry. If each is passed in the manner described, from below upward through only one side of the palate, both ends of each suture may be drawn out of the mouth and the needle removed. A single knot or a loop can be tied in the nasal end of one suture through which the nasal end of the corresponding suture on the opposite side can be passed, and thus drawn through both sides of the palate. The sutures can be passed thus in succession, care being taken that they do not become crossed within the nose, and that they are placed at regular intervals and at exactly corresponding points on the two sides. These sutures may then be tied, and what-

ever additional stitches are necessary may be so placed as to unite exactly the edges of the incision. Many surgeons will, with practice, find no difficulty in passing the sutures directly through both sides of the palate, on one side from the mouth to the nose, and on the other from the nose to the mouth. If, however, difficulty is encountered, the simple method just described will overcome it. The uvula itself is the most difficult part of all to suture accurately and symmetrically. If small flaps are turned back as suggested, care must be taken that they do not lead to confusion in the recognition of the true base of the uvula where it joins the soft palate.

FIG. 230. — Raspatories (for right and left sides) for Separating the Muco-periosteum from the Hard Palate. The blades are flat on the surface which is to be inserted next the bone, and are slightly rounded on the surface which lies next to the periosteum. The blades are also slightly convex on the flat side, in order that they may more readily follow the curve of the palate. The edges of the blades must not be sharp enough to cut the tissues.

Tension in the uvula is insignificant. Failure of union is due to the action of the tongue or to failure properly to appose denuded surfaces. It is usually advisable to suture the upper and posterior surfaces as well as the anterior lower surface of the uvula. This can be done if the uvula is drawn well forward and thus almost inverted. It is usually possible to place extra stitches in the upper surface of the soft palate in the same way, thus gaining additional apposition.

It is very important indeed that the stitches include a sufficient amount of the deep tissues of the palate. It is equally important that they should not include so much mucous membrane as to make it possible to drag undenuded mucous surfaces into the line of union.

If silk is used it may well be soaked in the compound tincture of benzoin. This facilitates tying the knots and also tends to prevent the spread of infection through the capillary spaces between the fibres.

(3) The third object, to secure an absence of tension along the line of union, depends on two conditions: first, absolute freedom of the flaps, and, second, such placing or reinforcing of the main sutures as to hold the united edges together for a long enough time and without any aid to be derived from sutures introduced solely to secure accurate coaptation. The freedom of the flaps depends chiefly on the lowering of their inner edges as they are drawn together in the median line. They thus become separated from the palatal bones and occupy a position nearer the tongue. (Fig. 227.) The lower down on the alveo-

lar processes the lateral incisions are made, the wider will be the flaps and the greater will be their ability to fall together. The lateral incisions should extend well in front of the anterior angle of the cleft, should be well down on the alveolar processes, and should be continuous behind with the incisions which are made to free the soft palate. These incisions should be made down to the bone.

While special raspatories (Fig. 230) are better, a blunt dissector will serve to free the flaps between the incision and the edge of the cleft. The utmost care should be taken to separate the flaps, not only as far forward as the anterior angle of the cleft, but well in front of it. Otherwise, there will be tension on the flaps and failure of union in the anterior angle of the wound. It is especially important that the flaps be separated for a considerable distance in front of the cleft in those cases in which the anterior end of the cleft is U-shaped and broad, rather than V-shaped and narrow. (Fig. 231.) Of course sufficient attachment in front is necessary to insure nutrition of the flaps. Most important of all, however, the flaps can never drop toward the tongue satisfactorily unless the upper mucous membrane is severed where it passes above the palatal bones to form the floor of the nose. This can easily be done by means of a blunt dissector or scissors. The failure to cut through this upper layer of mucous membrane completely, and far out at the sides, is the most common cause of tension on the flaps after they are sutured together.

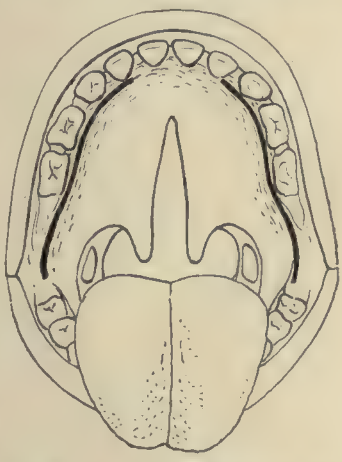


FIG. 231.—In this figure the lateral incisions are indicated by heavy black lines. They are to pass well in front of the anterior end of any incomplete cleft. The only precaution to be taken is to be sure that the attachment of the flaps in front is sufficient to insure their nutrition. Posteriorly the cuts extend outward and downward to the location of the last lower molar tooth or even outside of it. By keeping this end of the incision well out, a broader pedicle of the flap is secured, greater mobility is gained, and the gap left at the side by drawing the flaps together is narrower.

In freeing the flaps it is important that the hand which holds the dissector or raspatory should be braced in order to avoid any sudden slipping of the instrument and consequent risk of tearing the flaps. A tear is specially likely to occur just back of the hard palate.

In securing freedom of the soft palate the problem is somewhat different. A decided gain in the flaps is secured through a conversion of length into breadth, a change which is possible because of the absence of such resistance in the tissues as is found in the stiffer mucous membrane and periosteum of the hard palate. This conversion of length into breadth is at the same time objectionable from the point of view of functional use afterward. The lowering of the anterior part of the soft palate by freeing the upper layer of mucous membrane at the posterior edge of the palatal bones helps to gain freedom, and allows the soft palate also to go backward. Free lateral incisions carried through the mucous membrane at the sides of the soft palate, well outward as well as backward and downward toward the lower molar teeth, help greatly to free the flaps. After the mucous membrane is incised, the underlying tissues may be freed with a blunt dissector or with scissors. In this way the palatal muscles are cut from their attachments. It is usually unnecessary to break the hamular process if these free lateral incisions are made, and if the anterior edge of the soft palate is freed completely from the bone. These incisions do not interfere with the muscles or nerves of the palate sufficiently to cause paralysis afterward. The flaps should be absolutely free except for the attachment at the two ends. If they are insufficiently freed, the chances of union are greatly impaired. Too great emphasis cannot be laid upon this matter of absolute freedom of the flaps. In it lies the great secret of success.

In cases in which the cleft extends far forward or even into the alveolar process it is often a matter of great difficulty to free the anterior portion of the flaps sufficiently without endangering the nutrition which must come in part through the attached end. In such cases the specially devised right and left raspatories curved at right angles to the handle are of invaluable assistance. It is far wiser to leave a small hole unclosed at the anterior end of the cleft than to run any risk of impairing the nutrition of the flaps.

There are several methods by which cutting of the stitches may be lessened. One of the simplest is to tie a piece of tape around both flaps, passing it through the lateral incision on one side, above the united palate and out through the opposite lateral incision. The knot is to be drawn around at least as far as one of the lateral incisions. If left in the median line it will form a lump to be pressed by the tongue directly against the line of union. The tape should be at least a quarter of an inch wide and should be moderately firm. It should not be tied so tightly as to obstruct the circulation in the anterior pedicle of either flap. The objection to this method is that the tape becomes very foul and may cause considerable septic infection of the tissues covered by it. It is apt also to become displaced by the action of the tongue.

The flaps have been pushed together also by packing gauze into the liberating incisions at the sides. But this method is objectionable because of the foulness which speedily develops in such packing.

Another method by which cutting of the stitches may be diminished is by passing them through buttons of metal or celluloid. These buttons can easily be cut out of thin sheet celluloid such as is used in stocks. They should be from a quarter to three-eighths of an inch wide and from three-eighths to half an inch long. The holes placed about a quarter of an inch apart may be made with a glover's needle rotated between the thumb and finger as an awl. If these buttons are used it is well to substitute silver wire for the linen thread. The wire sharply bent on itself may be caught in a single knot in the thread and readily drawn through by a quick pull. It should first have been passed through both holes in one button. Both free ends should then be drawn through, and another button inserted on the opposite side. If preferred, one long strip may be used instead of the several smaller buttons. It is a little more difficult then, however, to have the holes come in exactly the right places. There is not the automatic adjustment of the strip as there is of the buttons.

Great care should be taken to avoid drawing the stitches too tightly, as, when the inevitable swelling comes, they may then cut badly. Furthermore, if the stitches are tight there is considerable risk of sloughing of the constricted part of the flap.

The use of a temporary plate to protect the palate from the action of the tongue has already been mentioned.

Some operators prefer not to use any special means of relieving tension. The action and pressure of the tongue are of course the main factors in preventing union. Thus, any method of suturing which irritates the tongue tends to defeat its purpose.

One very important matter is often overlooked. All injury done to the tissues by rough handling, either with forceps or with sponges, tends to delay and thus prevent union. It is very important, therefore, that the handling of the tissues be as slight as possible. The operation can be carried out in such a manner that forceps are used but once on each side in the whole operation, and then only to grasp tissue which is to be excised. At the beginning of the operation, the edge of the cleft should be seized accurately and securely just opposite the base of the uvula. Thus the edge of the cleft may be made tense, so that, without even a moment's yielding of this hold, the entire border on one side may be denuded, and a silk suture may be passed through the base of the uvula by means of which that side of the palate may afterward be controlled. The same manœuvre may then be carried out on the opposite side. These controlling sutures should be placed at exactly corresponding points on the two sides. Extreme care in this detail at the beginning of the operation will not only save much time in the end, but may also mean the difference between sufficiently accurate apposition to insure success, and such inaccuracy in apposition as to render failure of union likely. One of these sutures may ultimately be drawn through both sides, and serve as one of the sutures which unite the uvula and end of the soft palate.

Control of Hemorrhage.—The loss of blood in the operation occurs chiefly during certain steps. At the very beginning, while the edges are being denuded, the bleeding is moderate but soon ceases. It cannot be controlled easily and ceases spontaneously; so promptly, indeed, that no attempt need be made to check it.

By far the greatest loss of blood occurs when the two lateral periosteal flaps are raised from the sides of the hard palate. This is due to the fact that the palatal artery, which is of considerable size, is inevitably cut across. The lateral incisions should be made quickly and of sufficient length at the first cut. The bleeding may then be checked by pressure with the finger for several minutes. The flaps may then be raised with a periosteal elevator, and the bleeding again checked by pressure.

Anatomical Success after Operation.—It must be taken for granted that infection about the stitches is inevitable to a greater or less extent, and that the tongue will press and rub against the tightened and lowered palate. These two factors may lead to cutting of the stitches and to consequent failure to secure union. Sepsis cannot be entirely prevented. The mouth is foul at best. Below the nose a dead space has been formed between the palatal bones and the mucous membrane which has been separated from them. Cuts at the sides allow infection to pass from the mouth directly into this dead space. At the same time nothing hinders the advance of infection from above through the nose. At the beginning of the operation the nose and mouth should be thoroughly cleaned to remove any secretion. A thorough irrigation of the nose and mouth, with boracic-acid solution or boiled water, at the close of the operation, mechanically removes the mucus and blood-clots which have accumulated, and thus helps to keep the wound cleaner afterward. As far as possible the line where the edges of the wound meet should be kept undisturbed. Despite sepsis, despite the pressure and rubbing of the tongue, and despite the cutting of the sutures, union rarely fails to take place if only properly denuded, sound tissues are held together without tension for a proper length of time.

The pressure of the tongue upward against the palate is a factor which can be eliminated only by the use of a temporary plate. This can be applied only when there is a sufficient number of teeth to hold the plate in place. This device is seldom used at present.

It seems scarcely necessary to say that under no circumstances should solid food be allowed till union is firm, that is, until a fortnight has passed. During the first few days, if it seems desirable, nutritive enemata may be given, but this measure is usually unnecessary. As far as possible, the child should be kept quiet after operation. The same drugs may be used as after hare-lip operations. The mouth may be kept clean by rinsing with plain water immediately after liquid food is given. If necessary, hydrogen dioxide or some of the solutions commonly used as gargles may be employed for this purpose.

Chances of Functional Usefulness.—Perfect functional usefulness depends on the ability to shut off completely the naso-pharynx from the mouth. It must be taken for granted that the united palate will at first be too small for this purpose. Union usually converts the length, which may have been sufficient, into a breadth which is insufficient. A certain amount of shortening, with resulting inability to shut off completely the naso-pharynx, is thus inevitable. In time, this disability may be overcome in two ways. The development of the palatal muscles may lead to increased mobility. This practically always occurs to some extent; the degree depending largely on the care and persistence with which the muscles are trained. The inability of the palate to move backward may be compensated by an unusual development and control of certain fibres of the superior constrictor muscle of the pharynx. This compensatory hypertrophy of the superior constrictor, which pulls forward the posterior wall of the pharynx opposite the deficient palate, is not generally recognized. It enables the patient to draw forward a shelf-like fold of mucous membrane which thus completes the separation of the mouth from the naso-pharynx. The practical importance of this is very great indeed. It may give the patient a fairly normal voice even though the closure of the cleft has permanently left the palate abnormally short. The control of these muscular fibres can apparently be acquired by training. In order that this control may be favored in every possible way, it is of the utmost importance that no serious injury be done to the mucous membrane of the posterior pharyngeal wall. In almost all descriptions of the operation the preliminary removal of any adenoids is urged. This step may be distinctly harmful if the operation leads to the formation of scar tissue which interferes with the mobility of the posterior pharyngeal wall. If the adenoids are obviously a source of infection they should, without question, be removed. If, however, the mass of adenoids is large and projects forward it helps by just so much to fill the space which the short palate has to bridge over. It is always advisable, before operating upon the palate, to have the faucial tonsils removed. The two flaps may be approximated much more easily if they do not have to be pulled together around these two bodies, which often occupy a very considerable space.

Even in those cases in which, owing to neglect in training, the ability to shut off the naso-pharynx remains always incomplete, a certain functional gain will have been made by operative success. The liability to inflammatory disease of the nose and naso-pharynx is distinctly lessened, and so is also, in a corresponding manner, the liability to secondary inflammations of the middle ear. This gain is secured through the greatly lessened liability of the food to enter the nose.

Too great stress cannot be laid on the importance of patient, persistent vocal training in the after-treatment. It may frequently take several years of hard work before the speech becomes satisfactory. Without such training, speech may continue unsatisfactory. Operative success gives the opportunity to acquire functional success.

In a certain number of the more extreme cases the chances of union by the ordinary operative methods are so slight that the surgeon must choose between two alternatives. The first is to resort to special methods of operation, which, unfortunately, are usually best adapted to the youngest patients. The second is the abandonment of any operation and the use of an obturator.

The Use of Obturators.—The results from the use of well-fitting obturators are often so extremely satisfactory as to make operation inexpedient in certain extreme cases. Better functional results may be obtained from their use than from a rigid insufficient palate. The objections to obturators are, however, important. The initial cost, the frequently recurring expense for repairs and renewal, and the constant annoyance, are by no means inconsiderable. The most painstaking and intelligent care is necessary for the successful use of these devices. An obturator cannot, perhaps, be used quite so advantageously after an unsuccessful operation as before, but the harm in this respect resulting from the injury done during an operation is so slight, compared with the chances of immense gain, that, in cases in which there is any reasonable prospect of success, operation should be advised. (For further details see the article on "Prosthesis in Relation to Surgery of the Face, Mouth, etc.," in Vol. VI.)

Special Methods of Operating.—Several special methods of operating and variations in technique adapted to meet certain conditions should be fully understood, although, in the hands of those who have the widest experience, the old-fashioned methods are preferred. Wolff strongly advocated early operations. The essential point in his technique is the division of the operation, in very young children, into two or three stages, separated by intervals of from five to eight days. He first freed the flaps and later united them. He was careful to control bleeding by pressure.

In the case of a wide lateral cleft Lannelongue has folded down a flap of mucous membrane from the side of the nasal septum. This procedure is often most useful, but great care must be taken in separating the flap not to tear it at the junction of the septum and the palate. In placing the stitches, too, one finds that the nasal mucous membrane is very much more likely to tear than is that of the mouth. One may find too that the flap is somewhat redundant posteriorly unless care is taken to make it gradually narrower behind. Otherwise the deficiency of the flaps freed for the soft palate as compared with the flaps for the hard palate will cause great inequality of tension along the line of suture. Unfortunately, it is impracticable to bring down from the side of the septum a flap which will fill the gap in the back of the soft palate.

The exact technique of several of the more important special operations is here outlined, but the operator is strongly advised, unless he has had wide experience, to cling to the old and tried methods, and endeavor to win success through the minute attention to the details of technique.

The Davies-Colley Method.—N. Davies-Colley (*Brit. Med. Jour.*, 1890, II., 950) proposed a method for use in cases in which the ordinary operation had failed and also in cases in which the cleft in the hard palate was too wide to be bridged over by the ordinary method. At first, he regarded the operation as applicable only in these classes of cases, but later (Medico-Chirurg. Trans., 1894, Vol. LXXVII., p. 237) he recommended the operation as applicable in all cases. The first step consists in the separation of two muco-periosteal flaps, one from each side of the cleft. An incision about an inch long is made on one side just inside the last molar tooth, and through this opening a raspatory is introduced and the soft parts are separated from the posterior half of the hard palate. The incision behind should pierce the soft palate so that it may be separated from the nasal mucous membrane covering the hard palate. A second incision, beginning just at the front of the cleft and passing around it at a distance of about quarter of an inch from its border, is then made on the same side. As the soft palate is reached the cut is carried to the edge of the cleft, and the knife is then turned so that the soft palate is split into an upper and a lower layer. The muco-periosteum between the incision and the border of the cleft is then freed, the work of separation beginning at the incision and being pushed inward in such a manner that the flap thus formed may be folded up into the cleft as if it were hinged along the border of the cleft. A narrower flap is then freed and folded in a similar manner from the opposite side of the cleft. These two flaps of mucous membrane are later to be united, so as to form an upper layer of mucous membrane toward the nasal cavities. A long tongue-like muco-periosteal flap is then freed from the surface of the hard palate between the incision just made at the outside of the narrower infolded flap and the alveolar process. The pedicle of this flap lies posteriorly at the junction of the hard and soft palates. Care should be taken on this side to avoid injuring the palatine artery which lies in the pedicle. The two flaps folded upward from the sides are then united with stitches of fine silk or catgut, care being taken that their raw surfaces face downward and their mucous surfaces upward. In

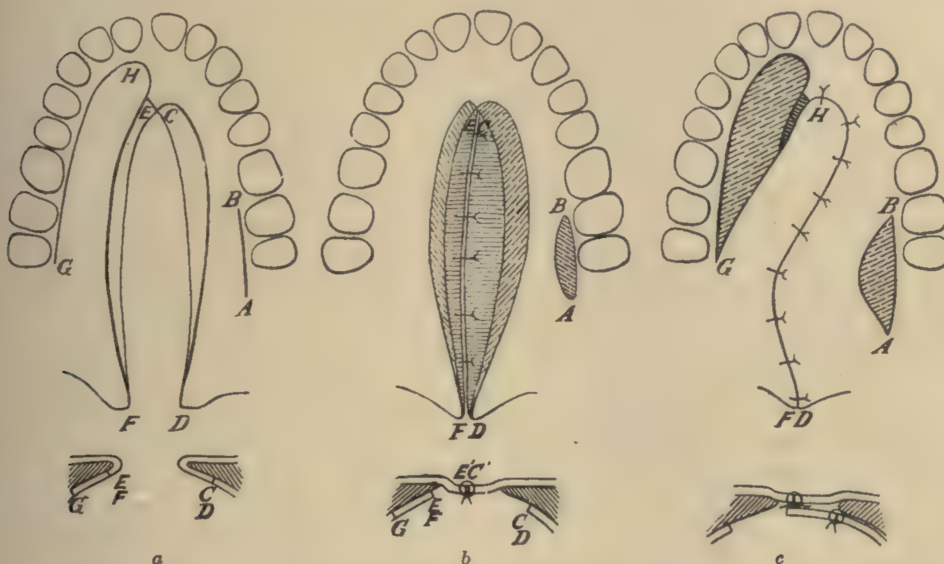


FIG. 232.—Diagrams Illustrating the Different Stages of the Davies-Colley Operation.

Incisions are made (see diagram *a*) on each side near the borders of the cleft, from the anterior angle backward. On one side the incision is made about an eighth of an inch from the edge of the cleft. On the opposite side the incision is far enough removed from the edge of the defect to provide sufficient tissue to close it. As the incisions extend backward into the soft palate they both approach the edge of the cleft, and in the posterior part of the soft palate are along the edge of the cleft, being made in such a manner as to split the soft palate into an upper nasal and a lower oral layer. The oral mucous membrane within these incisions (*EF* and *CD*) is then freed in such a manner that the flaps may be folded up into the cleft and united to form a new floor for the nose. Diagram *b* shows this stage of the operation completed.

In order to cover the raw and denuded surfaces left exposed on the oral side a long tongue-like flap of muco-periosteum, with its pedicle situated posteriorly (*GHEF*), is freed from that side of the hard palate from which the narrower of the two original flaps was taken. This flap is then swung across the under raw surfaces of the two previously united flaps in order to re-enforce and cover the line of sutures.

Diagram *c* shows the tongue-like flap sutured in place.

Posteriorly the oral mucous membranes of the sides of the soft palate are to be united. In order to gain greater freedom a liberating incision *AB* is made on the side opposite to that from which the tongue-like flap is taken. Through this incision, close to the posterior end of the alveolar process, the muco-periosteum may be dissected off from both the oral and the nasal sufaces at the back of the hard palate, and, if it is desired, the palate muscles may be cut. The smaller diagrams below show the conditions in cross-section.

the soft palate the edges of the upper plane are united in the same way. Thus the whole cleft is bridged over by a layer of muco-periosteum and soft-palate tissue, with a raw surface facing downward. (Fig. 232.) The inner border of the tongue-like flap is then drawn over and sutured to the outer edge of the incision on the opposite side. At the same time the margins of the lower planes of the soft palate are sutured together. Thus a second layer of tissue, with the mucous surface facing downward, bridges over the cleft. In this manner the raw surfaces of the two layers are brought into apposition. There is left exposed the raw surface from which the tongue-like flap was taken. The first incision made may be enlarged, if necessary, to prevent tension on the sutures.

The advantages claimed for the operation are these:—1. No tissue is pared away; 2. Much larger extents of raw surface are brought into close contact than in the ordinary operation; 3. The tension on the lower bridge which unites the sides of the hard palate is certainly much less than it is in other operative methods; 4. The pressure of the tongue tends to keep the raw surfaces of the two bridges in apposition.

The Ferguson Method.—Alexander Hugh Ferguson (*Jour. Amer. Med. Assoc.*, 1900, Vol. XXXIV., p. 1220) has described a method of operation with double flaps. The upper flaps are formed by cutting through the mucous membrane of

Fig. 233.—Diagrams Illustrating the Different Steps of the Operation of A. H. Ferguson. *a* shows the two flaps of mucous membrane, one from each side, folded upward into the cleft to be united to form the new floor of the nose. The raw surfaces of these flaps are toward the mouth.

b shows these two flaps already sutured, with the knots on the nasal side. The under layer of the muco-periosteal flaps are being sutured together.

c shows the cross-section of the flaps. The spaces *A* and *A′* may be packed with gauze to hold the two flaps, *BB′*, together.

the mouth about one-sixteenth of an inch from the edge of each segment, dividing all the soft structures as far as, but not through, the mucous membrane on the nasal aspect of the soft palate, and, in the hard palate, dividing the tissues to the bone. The free borders of the flaps are then folded up and stitched together with fine silk. The sutures are tied on the nasal surface in succession from before backward. Muco-periosteal flaps are then freed in the ordinary manner on each side and are united below the first set of flaps. In order to maintain the flaps in place without tension Ferguson packs the space left where the lateral incisions were made. (Fig. 233.)

Lane's Methods.—Arbuthnot Lane has devised various flap-forming methods which are especially applicable in very young children before the eruption of any teeth. The methods employed are in a general way similar to, though more elaborate than, those of the Davies-Colley operation. He utilizes flaps composed not only of the muco-periosteum of the palate, but also of the mucous membrane of the gums, of the external surface of the alveolar process, and even of the cheek. It is especially on the posterior aspect of the flap that tissue taken from the cheek may be found useful. Lane maintains that the earlier the operation is done the less is the liability of the temporary teeth to receive damage.

These methods, it should be remembered, utilize tissues which are not ordinarily considered available, and the flaps, in addition, are peculiarly liable to slough unless handled with extraordinary care. The condition which remains after sloughing of the flaps is of course worse than that which existed before operation.

An incision is carried outward and forward on one side from the anterior end of the cleft over the alveolar process to a point on its outer aspect. An

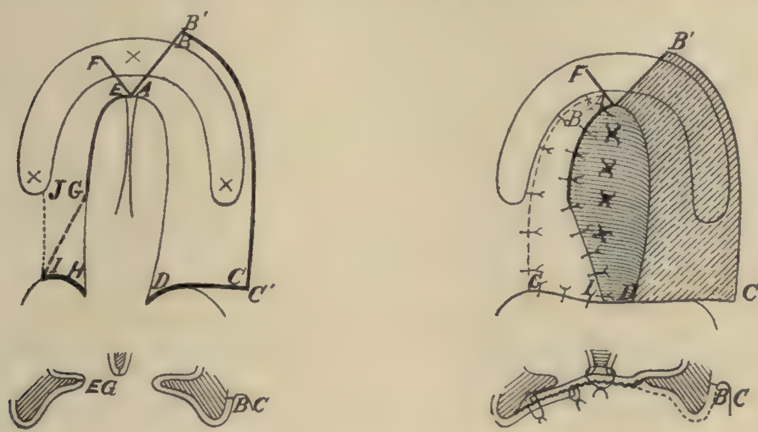


Fig. 234.—First Operation of Lane.

In the diagram on the left the incisions are indicated by the heavy lines. The curved space ××× indicates the alveolar process. A flap of mucous membrane and periosteum is taken from the hard palate and alveolar process anteriorly and from the oral mucous membrane and submucous tissues of the soft palate posteriorly on one side. The incision bounding this flap starts forward and outward from the anterior angle of the cleft (*AB*) and crosses to the outer side of the alveolar process. It then turns back along the outer side of the alveolar process and onward in a straight line behind it to a point directly outside the posterior border of the soft palate (*BC*). The incision is next carried directly inward, and then along the posterior border, to the uvula (*CD*). The flap is then to be freed from outside inward, so that it may be folded upward into the cleft as if hinged along the border of the cleft *AD*.

On the opposite side anteriorly a muco-periosteal flap (*FEGJ*) is freed from the surface of the hard palate through an incision made along the border of the cleft (*EG*) and carried forward and outward from the anterior angle of the cleft (*EF*). From the border of the cleft, at the junction of the hard and soft palates, the incision (*GI*) is carried backward and outward along the nasal surface of the soft palate to its posterior border and is then carried along the posterior border of the soft palate to the uvula (*IH*). Thus, by splitting the soft palate from the incision *GI* inward, a flap of nasal mucous membrane (*GIH*) may be folded down along the line *GH*. By splitting the remainder of the soft palate in the area *GIJ* a space is formed into which the entire flap of oral mucous membrane (*ABCD*) may be inserted above the flap *FEGIH*. Below, the levels of the incisions *EG* and *BC* are shown in cross-section. The incision splitting the mucous membrane along the lower border of the septum is also shown.

In the diagram on the right the arrangement of the flaps and sutures in the completed operation is shown. The shaded area *AB'C'D* represents the denuded area. A part of the flap folded up is left with its raw surface exposed on the oral side. A part is covered by the flap above which it is fastened. The four stitches in the median line represent the points at which the flap *ABCD* is sutured to the lower border of the septum.

Below the larger diagrams smaller ones are placed; they show the arrangement of the flaps in cross-section.

incision is then carried from this point backward along the outer surface of the alveolar process at about the level of the junction of the cheek and gum. This incision is carried backward, at the same level beyond the alveolar process, to a point opposite the posterior border of the soft palate. A third incision is then made inward from this point to the posterior border of the palate and along it to the uvula. (Fig. 234, *ABCD*.) The flap of muco-periosteum included between these incisions is freed from the outside inward so that it may be folded into the cleft. At the back part the mucous membrane and submucous tissues are freed from the muscles of the soft palate, which are thus not themselves disturbed. The pedicle of the flap lies along the margin of the cleft. On the opposite side an incision is made along the margin of the cleft from the anterior end as far back as the end of the hard palate. (Fig. 234, *EG*.) The uvula is then seized and an incision is carried outward from it along the free posterior margin of the soft palate for some distance. (Fig. 234, *IH*.) From the outer

Fig. 235.—Diagrams Illustrating the Modified Operation of Lane. They show the manner in which an asymmetrical cleft may be closed. The principles involved are exactly the same as those upon which the operation already described is based. The incision *ABCD* is carried far out beyond the alveolar process posteriorly in order to obtain sufficient tissue to fill the gap on the opposite side. The flap thus formed is folded along the line *AD*. An incision is made along the border of the cleft in the hard palate on the opposite side *HG*. The incision is then continued backward and outward along the upper surface of the soft palate and at a distance from the border of the cleft, *GF*. From the end of this incision the posterior border of the soft palate is split inward to the uvula, *FE*. The soft palate is then split from the incision *GF* inward to the border of the cleft, so that the part of the nasal surface of the soft palate thus freed (*GFE*) may be folded downward along the line *GE*. Through the incision *HG* the muco-periosteum is peeled off of the hard palate for a sufficient distance to allow the anterior part of the flap *ABCD* to be inserted above it. The posterior part of the flap is sutured in place above the flap *GFE*, which has been folded down.

The diagram at the right shows the arrangement of the flaps at the completion of the operation. The raw surfaces left exposed on the oral surface are shaded. On the left is the denuded area; on the right is the under surface of the folded-up flap.

end of this cut an incision is carried forward and inward across the upper surface of the soft palate to reach the posterior end of the incision along the free margin of the hard palate. (Fig. 234, *GI*.) The muco-periosteum covering the hard palate is then freed, the work of separating the tissues beginning at the edge of the cleft and advancing outward. To facilitate this, a cut may be carried forward and outward from the anterior end of the cleft toward the alveolar process. The triangular flap of mucous membrane and submucous tissue marked out on the upper surface of the soft palate is then freed from the underlying tissues so that it may be folded downward along the margin of the cleft. Furthermore, the mucous membrane remaining on the upper surface of the soft palate outside the triangular flap may be raised and folded upward so that the raw surface exposed upon the upper part of the soft palate may be increased in extent. Thus, on one side, a very large flap is formed which may be folded upward into the cleft like a door hinged along the edge of the cleft. The mucous surface of this flap will then be uppermost, toward the nasal cavity. The raw surface will be toward the mouth. (Fig. 234.) On the opposite side, anteriorly, a flap has been separated from the under surface of the hard palate, while posteriorly a flap has been folded downward as if hinged along the margin of the cleft. Thus a good-sized flap has been freed which has a raw surface above and a mucous surface toward the mouth. The two flaps are then to be brought into contact by their raw surfaces instead of by their edges. The large flap taken from one side is to be folded upward and tucked into place above the raw surface of the flap which has been folded down from the opposite side. The larger

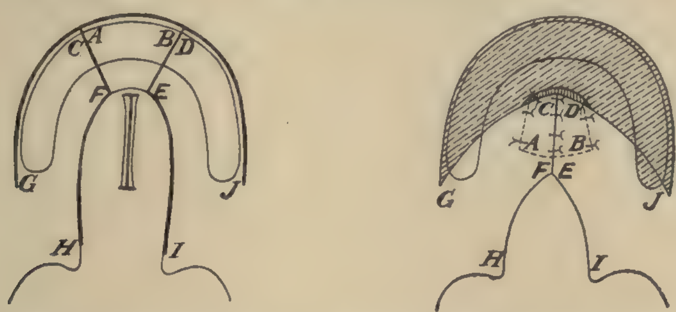


Fig. 236.—Diagrams Illustrating the Second Operation of Lane—first stage. That on the left-hand side shows the first stage of the operation. From points a little outside the anterior angle of the cleft an incision is made on each side and carried forward and outward to the outer side of the alveolar process (*ED* and *FC*). Incisions are then carried backward on each side, one along the border of the cleft in the hard and anterior part of the soft palate (*EI* and *FH*), and the other along the outer side of the alveolar process to its posterior border (*DJ* and *CG*). Between these incisions flaps of oral mucous membrane and periosteum are freed so that they may be swung inward to allow the union of their anterior borders in the median line. The flaps *GCFH* and *JDEI* are united by their borders *CF* and *DE*.

But before the flaps are sutured together the mucous membrane covering the alveolar process directly in front of the cleft may be freed and folded upward into the cleft in such a way as to form a new floor of the nose anteriorly and present below a raw surface against which the raw upper surfaces of the united lateral flaps may rest. *ABEF* is folded upward along the line *EF*.

The diagram on the right shows the arrangement of the flaps in the completed operation.

If it is desired, all three flaps may be sutured to the septum.

The utmost care is necessary lest the nutrition of the anterior flap be impaired.

In each of the lateral flaps the palatine artery should be preserved.

The denuded areas are shaded.

flap which is folded upward may, if feasible, be sutured to the refreshed mucous membrane of the lower edge of the septum. This is not essential. Another row of stitches should unite the overlapping flaps along the free margin of that which has been folded down. A third row should unite the two at the free margin of the upper flap. A final row of stitches unites the posterior borders of the two flaps.

It is plain that, as a result of these measures, there is left a very large denuded area from which the first flap was taken. A great objection to the operation is the extent of scar-tissue formation necessarily involved in the healing, which may lead to a stiff, immovable palate. (Fig. 234.)

Arbuthnot Lane has described numerous modifications of his operation, which may be used under varying conditions. They are more easily understood from the diagrams than in any other way. They are essentially similar to the operation just described. (Fig. 235.)

In case the cleft is so wide that it cannot be closed at one operation in the manner just described, Lane advocates the displacement inward of two flaps in a manner similar to that advocated by Taylor and described below. Lane, however, takes larger flaps which extend out upon the external surface of the alveolar process, and unites them by their anterior instead of by their internal borders. Another modification lies in folding backward and upward into the anterior part of the gap the median portions of the mucous membrane between the anterior ends of the two flaps. The nutrition of this median flap is very precarious, and the advantage of folding in this tab to cover the anterior ends of the two flaps on their upper raw surfaces is not likely to be such as to compensate for the damage done and the risk of sloughing involved. (Fig. 236.)

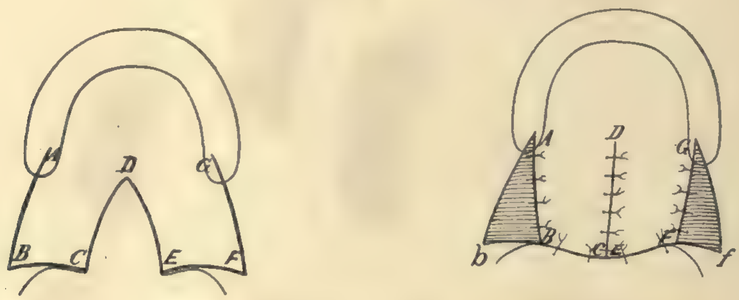


Fig. 237.—Diagrams Illustrating the Second Operation of Lane—second stage. In this procedure the posterior portion of the cleft is closed in a manner the reverse of that in which the anterior part was closed. Incisions are made along the borders of the cleft in the soft palate (*DC* and *DE*), and outward along the posterior borders of the soft palate, and then directly outward through the oral mucous membrane above the anterior pillar of the fauces. (*EF* and *CB*.) Incisions are then made from the posterior parts of the alveolar process backward and outward in directions parallel with the borders of the cleft (*AB* and *GF*), thus completing three sides of a parallelogram. The soft palate is to be split and the flaps of oral mucous membrane and submucous tissue thus formed (*ABCD* and *DEFG*) are to be swung together and united in the median line. (*CD* to *DE*.)

In the diagram on the right the arrangement of the flaps and sutures in the completed operation is indicated.

At a second operation, to be performed after an interval, two flaps of mucous membrane and submucous tissue may be freed from the muscles of the soft palate and displaced inward to be united in the median line. This second operation is the reverse of the first. (Fig. 237.) This procedure is of course applicable also in wide V-shaped clefts of the soft palate.

Fillebrown's Method.—Fillebrown (*Vermont Medical Monthly,* Dec. 15th, 1906) has proposed substantially the same method as that just described for closing a cleft in the soft palate. The only difference is that, in splitting the palate into two planes, the posterior border is left intact. Less freedom of the flaps is secured in this manner, but better nutrition may be expected.

Taylor's Method.—E. H. Taylor (*Dublin Journal of Medical Science,* 1900, Vol. CI., p. 427) has described an operation which is especially suited for those cases in which the cleft is wide anteriorly and extends far forward. He dissects out a muco-periosteal flap from the hard palate on each side. These flaps are left attached only at their posterior ends; in front, they are entirely free. The possibility of doing this and still maintaining the nutrition of the flaps depends upon the integrity of the palatine artery which emerges from the posterior palatine foramen at the inner side of and a little behind the alveolar process opposite the last molar tooth. The flaps are freed by curved incisions beginning opposite the last molar teeth and carried close to the alveolar border. In front, enough tissue must be left above the incisor teeth to hold a suture. Thus the palatine artery is included in the pedicle of the flap which is to be raised from the bone with a broad and rather blunt rugine. In order to allow greater freedom of the flaps the nasal mucous membrane at the junction of the hard and soft palates may be divided. This may be done slowly and under direct observation if the flaps which have been freed are reflected, but the dissection must not extend out so far as to injure the artery. The flaps are then to be united

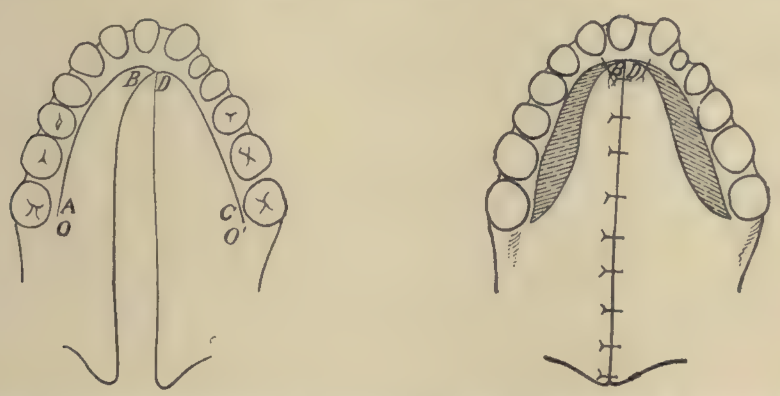


FIG. 238.—Diagrams Illustrating the Operation of Taylor. The operation is intended especially for clefts which extend far forward and are wide in front. The edges of the cleft are pared. The incisions *AB* and *CD* are made along the borders of the alveolar processes from the last molar teeth forward. The combined mucous membrane and periosteum is then freed on each side from the hard palate between these incisions and the cleft. The flaps thus freed are approximated and the two halves of the soft palate are united. Additional incisions may be made posteriorly, if necessary, but must not be allowed to injure the palatine arteries which emerge at *OO′*. The great objection to the operation, in complete clefts, lies in the fact that no freedom of the flaps is allowed at those points where the tension is usually the greatest.

to each other, and in front are to be sutured to the gum above the incisor teeth. If the flaps are not sufficiently free at the junction of the hard and soft palates an antero-posterior incision, which divides the fibres of the levator and tensor palati muscles, may be made on each side at the inner side of the hamular process. (Fig. 238.)

The Brophy Method.—The Brophy operation for closure of clefts in the hard palate was brought forward in 1893. It consists essentially of a crowding together of the two alveolar processes and palatal plates. It is described thus in Park's "Surgery":—

"After refreshing the edges of the cleft, including the surfaces of bone to be apposed, the cheek is raised, and well back toward the posterior extremity of the hard palate, just back of the malar process and high enough to escape all danger of not being above the palatal plate, a wire suture is carried through the substance of the bone, so as to come out in a corresponding position on the opposite side. Another wire is carried through the front portion of the superior maxillary in the same way. These two wires pass over the palate, one in front of the malar process and the other behind it. The free ends are passed through lead discs, and the wires twisted so as to approximate the palatal plates. (Fig. 239, *a*.)

"If it is impossible to close the fissure with these wires, owing to lack of tissue or firm resistance of the parts, a knife is inserted through the mucous membrane, just over the malar process, and swept around horizontally so as to cut a maximum amount of bone through a small opening. After this is done on each side, the bones are readily drawn toward the middle line. (Fig. 239, *b*.) The separation of the bones is attended with little hemorrhage. A few fine sutures are inserted to insure perfect coaptation of the edges of the wound."

The operation can be performed satisfactorily only in early infancy, while the bones are still soft and pliable. The operation does not give any more tissue from which to form the new soft palate.

The objections to the operation are:—The disturbance of the germs of the molar teeth of the temporary and possibly of the permanent set; the possi-

FIG. 239.—Diagrams Illustrating the Operation of Brophy.

Diagram *a* shows in cross-section the manner in which the sutures are to be passed to narrow the cleft by the approximation of the sides. *N*,*N*,' indicate the nasal cavities. *A*,*A*,' indicate the rudimentary antra. *P*,*P*,' indicate the alveolar processes on the two sides. The sutures are passed above the palatal plates through the upper parts of the alveolar processes and are quilted through lead plates and forcibly tightened.

Diagram *b* shows how, by horizontal incisions above the sutures, greater freedom in approximation of the sides may be obtained.

bility of contracting the palate to an abdormal extent; and the possibility of abnormal narrowing of the nasal cavities. Resulting dental defects may be corrected later, but the considerable mutilation may interfere seriously with the development of the alveolar processes. In a few cases the upper alveolar processes are separated to an abnormal degree so that the upper jaw is more than ordinarily broader than the lower jaw. In selected cases the operation may be of special value.

Numerous attempts have been made to close the gap in the palate by the introduction of other tissues. Gersuny (see von Eiselberg, *Archiv f. klin. Chir.*, Bd. LXIV., Hft. 3) has taken a flap from the tongue; Schoenborn (abstract in *Archiv f. klin. Chirurgie*, 1876, Bd. XIX.) has taken one from the posterior wall of the pharynx; Delarme (Bulletins et mémoires de la Société de Chirurgie, 1897) has taken a flap from the interior of the cheek; and Rose (*Archiv f. klin. Chirurgie*, Bd. XXIV.) has taken one from the lip. Kraske (*Beitraege zur klin. Chirurgie*, Bd. XIV.) has sewed the inferior turbinated bones into the gap. Blasius (see von Eiselberg, *Archiv f. klin. Chirurgie*, Bd. LXIV., Hft. 3), Rotter

(Bericht der Verhandlungen des ersten Congresses der deutschen Gesellschaft f. Chirurgie), Bardenheuer (Bericht der Verhandlungen des 21ten Congresses der deutschen Gesellschaft f. Chirurgie) and von Eiselberg (*Archiv f. klin. Chirurgie*, Bd. 64, Heft 3) have taken skin from other parts of the body. Such procedures are very rarely applicable.

Acquired Cleft Palate.—A word should be said regarding the treatment of clefts of the palate the result of accident or disease. Children occasionally tear the palate by falling while carrying sticks in their mouths. The palate has been torn by a partially etherized child grasping a Gottstein curette inserted to remove adenoids. Injury to the mucous membrane of the hard palate not involving the bone will have no serious after-consequences. The advisability of suture must depend on the circumstances in each case. Injuries of the soft palate are more serious when they involve the entire thickness of the palate. As a general rule, it is safe to say that all tears in the soft palate should be sutured immediately. This should be done before any inflammatory reaction has occurred and will ordinarily require no refreshing of the edges. Immediate suture is more imperative in cases in which the tear extends backward through the posterior border of the palate than in a simple puncture, which may close spontaneously by granulation and cicatrization. If for any reason suture is impossible before there is marked inflammatory reaction, it would be well to delay suture until all the raw surface had healed and the inflammation completely subsided, except in those cases in which the injury is so extensive that delay must inevitably lead to extreme deformity.

Clefts in the palate the result of disease are almost invariably syphilitic in origin. They are always an indication of neglect or inefficient treatment. No operation whatever should be undertaken in such cases until months have passed without indication of any active syphilitic process in any part of the body.

Secondary Operations for Correcting Defects after the Primary Operation.—In many cases of single hare lip, in spite of every effort made at the time of the first operation to correct the deviation of the septum, the flattening of the ala, and the sinking of the floor of the nose, one or more of these defects, of greater or less conspicuousness, remain. Under these circumstances secondary operations may be necessary.

The steps required for correcting the deformities vary according to the conditions present in each case. In the first place, one should observe carefully whether the deformity of the nostril is due to a deviation of the septum, to the sinking of the floor, or to a displacement or a deformity of the ala. It will usually be found that the greater part of the deformity is due to a deviation of the septum. Such a deformity may be corrected in part by an extensive plastic operation on the underlying palatal plates and alveolar processes, but only at the cost of great mutilation of the jaw and risk to the teeth, which have not yet erupted. It is much simpler and usually equally satisfactory to free the anterior part of the septum together with the mucous membrane of the floors of the two nostrils from the underlying bones and displace them toward the side of the broad nostril. This may be done by raising the upper lip and cutting the mucous membrane off from the bone with a pair of blunt-pointed curved scissors. It is extremely difficult to keep from perforating the floor of the nostril on the affected side, but this should be avoided if possible, unless it seems best to excise a certain amount of tissue in order to narrow the floor of the nostril. When the mucous membrane is thoroughly freed on each side, the anterior part of the septum may be cut through horizontally close above the palatal plates. The only risk, in such a procedure, is that of causing an abscess of the septum, but this complication rarely occurs, and, with the absolutely free opening below in the space back of the upper lip, the chance of any extensive necrosis of the cartilage is remote; nevertheless, the surgeon must remember that cartilage is destroyed by suppuration and that, once destroyed, it is never regenerated.

At the time when the displaced septum is brought into its new position the mucous membrane and skin below the nostrils should similarly be moved. In this manner there is produced a thinning of these tissues on the sound side and a

a *b* *c*

FIG. 240.—Diagrams Illustrating Different Operations for Correcting Defects in the Nostrils.

a shows the manner in which a wedge-shaped piece may be excised from the floor of the nostril when it is abnormally broad.

b shows the floor of the nostril united by sutures after the removal of the wedge. The widths of the two nostrils are now equal, but on the left side the outer border of the nostril is still depressed. The manner in which a wedge-shaped piece may be excised is indicated.

c shows the resulting changes in the width and outline of the nostril, changes which bring it into conformity with that on the opposite side, except that the slight deviation of the septum away from the affected side still persists.

thickening on the affected side. Thus the second object is in a measure accomplished. If the change made in this way is not enough to raise the depressed floor of the nostril sufficiently, the lower parts of these tissues which lie below the sides of the nostril must be approximated. Thus the central part of the mucous membrane is pushed upward and forward. This procedure may be followed in those cases in which there is no deviation of the septum, but under these circumstances the ala must be freed liberally to allow approximation of the sides of the gap. Substantially, the operation consists in making a horizontal cut below the nostril and suturing its margins as if it were a vertical one. In any case it is essential that a very free incision should be made. No visible scar is created, because the cut is made under the lip, which is drawn upward. Owing to the elasticity of the cartilages a certain amount of yielding of the scar—which means a tendency toward reproduction of the deformity—is inevitable. Therefore, it is necessary, just as in the primary operation, to allow for this by slightly overcorrecting the defects.

In an entirely different manner an oblique incision may be made in the floor of the nostril and one side may be drawn over the other. Thus the nostril is narrowed at the same time that its floor is raised. The spot at which it is raised the most is determined by the location of the cut. The change in the breadth of the nostril will occur either on the septal or on the alar side according to the direction and extent of the incision.

Displacement outward of the ala may be corrected in the same manner as is a displacement of the septum, viz., by an incision made with scissors under the lip.

Still more difficult to correct are defects in the shape of the nostril. The curve of the free edge of the nostril and ala on one side, while not in itself abnormal or objectionable, may not correspond with the shape of these parts on the opposite side. Under these circumstances the position and shape of the ala may be changed, or the shape or length of the free edge of the nostril may be altered. One of the more common deformities is due to a sinking in of the middle of the free border of the nostril about midway between the ala and the lobule of the nose. (Fig. 241, *b*.) This often is so marked as to make the nostril very flat, although usually the width is also increased. The deformity may

FIG. 241.—Diagrams Showing the Manner of Terminating the Incisions in the Side of the Nose when a wedge-shaped piece involving the whole thickness of the parts has been removed. *a* shows the perpendicular borders brought together. The transverse incision across the upper end of the perpendicular ones allows a more sudden change in contour above and below this level than could otherwise be obtained.

b shows how an overcorrection of the flattening of the side of the nose may be obtained.

be corrected by the excision of a wedge-shaped piece from the inner surface of the deformed border of the nostril. In cases in which the length of the border is not increased the wedge should not extend out through the skin, but should include only the mucous surface. In case the length is increased, the wedge may include the entire thickness of the border. At the ends the wedge-shaped piece may taper to a point, or, if it is necessary to make more sudden changes in the direction and shape of the parts, the wedge may be limited by incisions across the ends. (Fig. 241.) Deformities of this sort are never to be corrected until any existing deformity of the septum or of the ala shall have first been corrected, for, in changing the ala or the septum, the bases of support for the intermediate parts are changed. It is well in such cases to wait for several months to elapse after one operation before undertaking another, in order that the parts may have an opportunity spontaneously to adapt themselves to the changed conditions.

In spite of the warning against undue readiness to interfere with the underlying bones it is often absolutely necessary to change the relations of these before the overlying tissues can be satisfactorily corrected. The introduction of paraffin or of some similar support may in certain cases be wise, and is always to be considered before any operation upon the bones is undertaken.

In cases of double hare lip the deformity which most frequently needs correction is a broadening and flattening of the nose. In producing the flattening a most important factor is the shortness of the septum, which is associated with the forward displacement of the tab of tissue which grows on the intermaxillary bone and which should form the median portion of the upper lip. The length

Fig. 242.—Diagrams Showing the Operation of Marx for pushing forward the tip of the nose and lengthening the exposed part of the septum. A V-shaped cut is made, the sides of the V reaching from each nostril far back into the septum. This is then closed in the form of a Y. At the same time the nostrils may be narrowed by the excision of the shaded wedge-shaped pieces shown in *a*. In *b*, not only is the tip of the nose pushed forward, but the nostrils are narrowed to their proper width.

of the septum may be increased by making an inverted V-shaped incision in its exposed lower portion. The apex of the V should be forward toward the tip of the nose. The two arms of the V should spread outward into the lip just where it merges into the floor of the nostril on each side. In this manner the tip of the nose may be freed sufficiently to allow it to be drawn forward. The V-shaped incision may then be sutured in the form of a Y. In order to gain freedom of

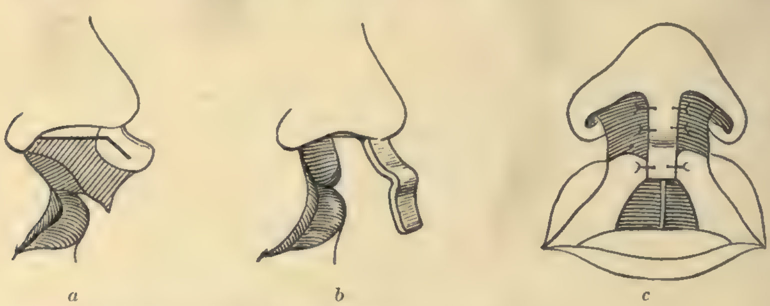


Fig. 243.—Diagrams Illustrating the Operation of Lorenz.

Diagram *a* shows the projecting intermaxillary bone, with the short distance between the tip of the nose and the median portion of the upper lip. The heavy lines indicate the manner in which the median tab of skin may be split so as to be unfolded, as shown in *b;* and they also show the direction in which the incision is to be made in order to remove the intermaxillary bone. If it is desired to preserve the intermaxillary bone, the horizontal cut would have to be made at a higher level. It is of course unnecessary to split the median tab of upper lip if it is long enough to cover the exposed part of the septum.

Diagram *b* shows the intermaxillary bone removed and the central tab of skin split and unfolded, being left attached only at the tip of the nose.

Diagram *c* shows from below the tab of skin sutured in position along the exposed lower border of the septum. The mucous membrane is sutured between the alveolar processes.

the deep tissues, the original incisions must be carried far into the septum. (Fig. 242.)

An entirely different principle may, however, be adopted for correcting the deficiency in the antero-posterior length of the septum. The method may be used as a secondary procedure, but is especially applicable as a modification in the original operation when the septum is so short as to make it certain that the ordinary method will yield an unsatisfactory result. The details of the procedure are as follows:—

The median tab of the upper lip may be freed from below upward so that it is left attached only at the base of the septum. The septum is then cut across inside the nose so that the tip of the nose may be drawn forward or the intermaxillary bone pushed back. (Fig. 243, *a*.) If the cut be made far enough back, there will be left, in front of it, sufficient tissue to allow firm union to take place between the part of the septum which is drawn forward and the maxillary bone below it. In this manner firm support for the tip of the nose is assured. The portion of the septum thus drawn forward and left exposed immediately behind the median tab of skin may then be covered by folding this back and using it to complete the free margin of the septum. The sides of the lip may then be united to each other directly below the median tab instead of being united to the median tab. If it is desirable to gain a still greater length of flap the tab may be split and the mucous membrane as well as the cutaneous surface utilized. (Fig. 243.)

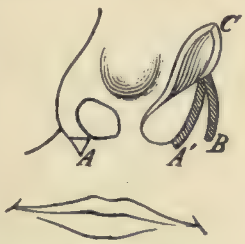


FIG. 244.—Diagram Showing the Method by which the Location of the Ala may be Changed.

A indicates the manner in which the ala is to be freed by a wedge-shaped cut extending into the substance of the cheek. *A'* indicates the gap from which the ala has been folded upward. *B* indicates the incision into which the ala is to be inserted. *C* is the edge of the ala taken from *A'* and to be inserted in *B*.

In many cases, however, the nose itself is sufficiently prominent. It is flattened merely when considered in reference to the intermaxillary bone immediately beneath it. Under these conditions excision of the intermaxillary bone may be considered. (Fig. 243.)

Undue broadening of the nose may most easily be corrected by resecting a wedge-shaped area from the floor of each nostril, thus narrowing them and approximating the alæ, which of course must be thoroughly freed from the underlying structures. (Figs. 240 and 242.)

It is rare that the nostrils are too narrow, but in cases in which the intermaxillary bone has been excised and the tissues of the lip on either side united without the interposition of the central tab of skin, this may be the condition. The alæ may be relocated by dissecting them off from the cheeks. The incisions which free them should be carried, in the shape of a wedge, into the tissues, so that the sides of the gap thus created may be approximated easily, and also in order that the edges of the alæ may be inserted into incisions cut further out, at the desired point, into the tissues of the cheek. If the ala is located abnormally, incisions may be made in the fold between the ala and the cheek, in the upper lip just below the ala and floor of the nostril, and if necessary downward and outward from the junction of these two incisions above the naso-labial fold. Thus a V-shaped or a Y-shaped series of incisions are made which permit considerable change in the position of the parts.

Flaws in the lip may be more readily corrected than those in the nose. An irregularity in the line between the skin and the red border may be easily corrected by a minor plastic operation. An asymmetry in the amount of the red border exposed on either side of the line of union is usually more readily corrected by excising a small strip of tissue from the inner surface of the lip on the side where the red border is redundant than by attempting to evert tissue on the side on which the red border is deficient. More disfiguring still is a deficiency in the height of the lip at the line of union, which brings some of the teeth into view. A defect of this sort may involve either the red border alone or both skin and red border. A defect of the red border alone may be rather hard to correct because of the tendency of scar tissue to cause it to contract. Such a condition should always be avoided by leaving a little redundant tissue at the end of the operation to counteract any future cicatricial contraction. A defect involving both skin and red border may be corrected by some such procedure as that of Nélaton already described.

SURGICAL DISEASES AND WOUNDS OF THE EYE.

By GEORGE C. HARLAN, M.D., Philadelphia, Pa.

I. DISEASES OF THE EYELIDS.

As the different tissues of the eyelids are so closely connected, and the diseases of one so frequently involve one or more of the others, it is hardly possible to classify these diseases distinctly, but they will be considered in a general way with reference to the skin, the muscles, the tarsus, lashes and glands, and the conjunctiva.

Erythema.—Erythema of idiopathic form is rare. It is usually due to local irritation, or occurs as a symptom of disturbance of the circulation from general causes. There is a superficial redness, disappearing under pressure, sometimes a slight swelling and a burning sensation, but no decided pain. It is usually transient, and requires no treatment but attention to the cause. Sedative applications may give relief.

Abscess of the Lid.—Abscess of the lid may result from traumatism, from caries of the orbital margin, or from suppuration of the frontal sinus. Idiopathic abscess is rare, except in badly nourished children. When situated in front of the lachrymal sac it may be mistaken for dacryocystitis, and when an abscess of the upper lid discharges through its conjunctival surface, it presents much the appearance of purulent ophthalmia.

Œdema.—The skin of the lid is so delicate and distensible, and so loosely attached, that it readily becomes œdematous. Œdema may result from local congestion of the lids or conjunctiva, or from obstruction to the circulation in the orbit or behind it, but is frequently due to disturbance in the general circulation, and is an important symptom of affections of the heart or kidneys, or of arsenical poisoning. No local treatment is usually required, but, if the swelling is so great as to interfere with the opening of the eye, punctures with a lancet and the application of pressure may give relief.

Erysipelas.—Erysipelas of the lids is not uncommon. The character of the tissues predisposes to excessive œdema, and the swelling is often so great that it is impossible for the patient to open the eye and difficult for the surgeon to examine the eyeball. It occurs usually in connection with facial erysipelas. In the phlegmonous form the disease may involve the capsule of Tenon and the orbital tissue, and result in blindness from optic neuritis or from pressure upon the optic nerve. In a few cases the infection has extended along the sheath of the nerve and set up a meningitis with fatal result. The treatment is the same as in other regions. One of the best applications is ichthyol ointment. If suppuration threatens, warm antiseptic fomentations may be used, and collections of pus, particularly in the orbit, should be promptly and freely evacuated.

Eczema.—Eczema of the lids is often a very troublesome and obstinate affection, particularly in the case of badly nourished children with phlyctenular ophthalmia, photophobia, and lachrymation, as the orbicular spasm and the discharges from the conjunctiva are a constant source of irritation. The sensitiveness of the delicate skin makes the burning and itching more unbearable, and its distensibility predisposes to greater swelling than in other regions. In the acute stage soothing applications, such as glycerite of starch and ointments of oxide of zinc or acetate of lead, are agreeable and useful. Acetate of morphia may be added to the latter to relieve the itching. When there is excessive secretion, frequent dusting with finely powdered oxide of zinc or aristol may be of use. When crusts form, they may be removed by leaving an ointment of sodium bicarbonate on the part during the night and wiping it off with absorbent cotton before other applications are made. In the chronic form more stimulating applications are required. One of the best is carbolic acid, which also relieves the itching. It may be combined with some mercurial. An excellent ointment is

Acid. carbol.	gr. ij.
Hydrarg. ox. flav.	gr. iv.
Ung. zinc. oxid.	ʒ i.

The part should be kept clean and dry with absorbent cotton, and water or other fluid should not be allowed to touch it. The general condition should be carefully treated. Syrup of iodide of iron is much used in the case of children with phlyctenular ophthalmia, and arsenical preparations are highly recommended.

Herpes Zoster Ophthalmicus.—This affection is characterized by the occurrence of vesicles along the course of the filaments of distribution of the ophthalmic branch of the fifth nerve. These vesicles never extend beyond the median line unless the affection is bilateral, which is rare. The disease may appear suddenly, or the eruption may be preceded by neuralgia, more or less severe, for hours, or days, or even weeks. In severe cases the vesicles become pustular and are followed by ulcers which may leave permanent scars. The patient complains of a sensation of smarting and burning, there is generally considerable febrile reaction, and the skin is swollen and red and shining, presenting a close resemblance to erysipelas, for which this disease is frequently, not to say generally, mistaken, even by experienced practitioners. It may be distinguished by its strict limitation to the median line and by the anæsthesia that nearly always accompanies it. Its pathology is obscure, but the affection is known to be of a neurotic character. In a case reported by Weyss,* post-mortem examination showed extensive lesion of the Gasserian ganglion.

Local treatment is directed chiefly to the relief of pain. The applications recommended in the acute stage of eczema give relief, and the continuous current is highly recommended. Hypodermic injections of morphia are often necessary. Large doses of quinine have seemed useful in some cases. Corneal and iritic complications should be carefully looked for and treated.

Blepharitis Marginalis (Ciliary Blepharitis, Blepharo-adenitis).—This affection varies in degree from a slight hyperæmia to a chronic inflammation involving all the tissues of the lid margin. In bad cases the lashes are matted with a dense crust formed of the altered secretion of the Meibomian and sebaceous glands and inflammatory exudation. The lashes are loose and may come away with the removed crust, and there are small points of ulceration along the lid margin. According to some authorities, the inflammation is generally of an eczematous character. If it extends deeply and lasts long, the bulbs of the cilia are involved and the lashes may be permanently lost or given a wrong direction by cicatricial contraction (trichiasis), thus causing them to impinge upon the eyeball. The final condition in the worst cases is a cicatricial, rounded, everted lid margin, without lashes or Meibomian ducts (*lippitudo*).

The simple hyperæmia of the lid margins is often a most rebellious affection. It occurs most frequently in blondes, and is an annoying disfigurement to many a pretty face. The eyes are apt to be irritable and watery and sensitive to light and dust, and the edges of the lids are red, a condition commonly called "blear eye." It may be kept up by the strain of some refractive or muscular defect which should be carefully sought for and corrected as the first step in treatment. The best local application is yellow oxide of mercury, gr. ¼ to ʒ i. of simple cerate or alboline, applied at bed-time and left on during the night. The eyes should be used as little as possible, particularly at night, and the general health should be looked after. Tonics and chalybeates are often useful. Many cases resist all treatment. In the severer forms of blepharitis the crusts must be removed with absorbent cotton and warm water to which sodium bicarbonate may be added. If the crusts are very dense, it is well to retain the wet cotton on the eyes for a time with a bandage. An occasional application of silver nitrate, gr. ii. to x. ad ℥ i. of distilled water, to the lid margin will hasten the cure, and the yellow-oxide ointment may be used in the proportion of gr. ss. or gr. ¼ to ʒ i. If there is much photophobia smoked glasses are useful. An accompanying conjunctivitis or lachrymal obstruction may require attention.

Phthiriasis ciliorum.—This is an affection of the lid margin due to the presence, in the lashes, of the pediculi pubis, which sometimes also infest the eyebrows, but the pediculi capitis are never found in the lashes or brows. The irritation of the parasites causes an inflammation of the lid margins which closely

* Wecker. "Traité Complet d'Ophtalmologie," vi., p. 58.

resembles blepharitis marginalis, for which it is likely to be mistaken. Close inspection, particularly with a lens, will reveal the pediculi and their eggs clinging to the roots of the cilia. They are soon destroyed by an application of yellow oxide or other mercurial ointment.

Canities (Poliosis).—This affection is characterized by an absence of pigment in the cilia. It may be confined to a part of the lashes of one lid, or may affect all of both lids, and the eyebrows as well. It is usually congenital, but is thought to be occasionally of neurotic origin. No treatment is of use.

Madarosis.—Madarosis, or absence of the lashes, may be congenital or acquired. It is sometimes a result of syphilis. Treatment is not likely to be of avail.

Rhus Poisoning.—This variety of poisoning, from contact with the *Rhus toxicodendron* (poison oak), or *Rhus venenata* (poison ivy), causes a violent inflammation of the skin of the lids, with great swelling which often makes it impossible to open the eyes. There are patches of vesicles exuding a yellowish fluid, and intense burning and itching. Many doctors and nearly all old women have a specific, but it owes its reputation to the facts that the disease is self-limited and that the acute symptoms subside in a few days. Nothing is more soothing than the dilute liquor plumbi subacetatis, to which acetate of morphia may be added.

Chromidrosis (Colored Sweat).—This affection occurs most frequently on the lower lid. There is a dark blue or black stain, which is easily removed, but soon returns and may last for several years. It has often been simulated by hysterical patients with the use of indigo, plumbago, or soot. It is generally considered an affection of the sweat glands, but its pathology is unknown and its treatment empirical. Various stimulant and astringent applications have been recommended.

Xanthelasma.—Xanthelasma is a smooth, yellowish, slightly raised patch of an irregular oval form. According to Waldeyer, it consists of fatty degeneration of connective-tissue corpuscles. The treatment is excision or electrolysis. (Villard et Bosc, *La Clinique Oph.*, January 10th, 1903.)

Milium.—Milium is a small rounded pearly tumor, about the size of a millet seed, consisting of the contents of a sebaceous gland with an obstructed duct. It requires only puncture and evacuation.

Molluscum Epitheliale (Molluscum Contagiosum).—Molluscum epitheliale is a small whitish tumor containing a cheesy mass which consists of degenerated epithelial cells and albuminous corpuscles. The tip is flattened and has a dark spot in the centre, the aperture of a follicle. It originates in a diseased sebaceous gland. It was formerly supposed to be contagious, but is not now so considered. It should be opened and the contents pressed out. Sometimes it is necessary to excise the walls, or to cauterize them with nitrate-of-silver stick.

Malignant Pustule.—Malignant pustule has frequently occurred on the eyelids. The disease has already been discussed in Volume II. The pathology and the treatment are the same as in other regions, except, perhaps, that the thermo-cautery should be used rather than the caustics, which act more deeply.

Hordeolum, or **Stye.**—This is a localized inflammation of the anterior lip of the lid margin, with a minute gangrenous slough of the subcutaneous tissue, practically a furuncle. There are usually more or less conjunctivitis and increased secretion of the Meibomian glands, the discharge from which forms a crust upon the lashes. The œdema of the thin and loose skin often extends over the whole lid, causing considerable swelling. Styes are usually recurrent, and may be an indication of some disturbance of the general health. Not infrequently there is a continuous series for weeks or months. A hordeolum nearly always suppurates and ruptures in a few days, but occasionally it undergoes resolution, when a small lump ("blind stye") may remain for weeks, or even require opening and cauterizing before it disappears.

In the beginning of a stye relief may be afforded by the application of a lump of ice in the fold of a handkerchief, but when suppuration is inevitable it should be hastened by hot applications, and an early incision should be made. In cases of recurrence refractive errors should be corrected and all sources of irritation should be avoided. Tonics may be needed, and the condition of the lid margin is often improved by the application of the yellow oxide ointment.

Warts.—Warts are best removed with a ligature of fine silk.

Horny Growths (Cornua cutanea).—These sometimes attain considerable size. The base should be cauterized after the growth has been removed.

Epithelioma.—Epithelioma, which usually affects the lower lid, is quite common. It generally commences as a warty excrescence, or as a tubercle or nodule. The warty variety is more superficial and less malignant and progresses more slowly, sometimes remaining nearly stationary for years. The nodular form progresses more rapidly and has a greater tendency to burrow into the orbital tissue—for which reason it has been sometimes termed phagedenic,—but either form may eventually involve the contents of the orbit and terminate fatally by extension to the brain or by exhaustion of the patient. The skin becomes excoriated and secretes a fluid which forms a crust beneath which is a ragged ulcer, or the disease may commence as a fissure or small ulcer, and extend in all directions as a rodent ulcer.

Epithelioma in its earlier stages, when the crust has separated and the disease exists as a small ulcer, may be mistaken for lupus or syphilitic ulcer. It is a disease of advanced age and of comparatively slow progress, the edges of the ulcer are hard and usually everted, and it is apt to bleed easily. The patient's history and general health will often throw light upon the diagnosis, and in doubtful cases the therapeutic test should be tried.

The proper treatment is to destroy the tumor by caustics, by excision, or by the employment of the x-rays or radium. If the ulcer is small, superficial, and of slow progress, it can often be made to cicatrize and to remain cicatrized for a long time by the use of caustics. I have found the mono-chloracetic acid an excellent caustic in these cases. It causes almost no pain, and may be applied freely and frequently. The *x*-ray treatment has proved successful in a number of cases, even in the more advanced stages. In excision the cuts should be carried well through the sound skin and the lid should be restored by some form of blepharoplasty. (See page 570.)

Syphilis.—A chancre or primary syphilitic ulcer on the eyelid is rare, but has been met with in a number of cases. It has usually been situated at the lid margin, and some observers have thought that the infection was lodged in the ducts of the Meibomian glands.

Secondary syphilitic eruptions and ulcerations may also occur on the lids, generally in connection with secondary manifestations in other parts.

Syphilitic ulcers which result from the breaking down of gummata, and which may therefore be considered tertiary, are more likely to present difficulties of diagnosis. The lid margin, where the skin passes over to mucous membrane, is the usual seat of these ulcers.

Lupus.—Lupus is comparatively rare. It is a disease of youth, usually occurring in badly nourished subjects of the poorer classes, under twenty years of age, and almost invariably of foreign birth. The ulcer is superficial, its secretion scanty, and its progress very slow. It is painless, but tender to the touch. The tubercles that precede the ulceration are frequently multiple and coalesce. The discovery of the bacilli of tuberculosis would confirm the diagnosis, but they are few and likely to escape detection.

The local therapeutic measures are: scraping with the sharp spoon, destruction by caustics, preferably the actual cautery, and excision. The general treatment, which is important, is that of other tuberculous manifestations.

Angioma.—Angioma is not uncommon on the eyelids, and is met with in several forms. The capillary angioma (*Nævus maternus*), or "mother's mark," is a congenital condition due to excessive development of capillaries, and is of a bright red or "port-wine" color, according to the predominance of arterial or of venous vessels. It is flat or slightly raised. It is more or less disfiguring, but otherwise harmless, and usually permanent. When the larger terminal vessels are involved (*telangiectasis*, or enlargement of end vessels) a tumor is formed—the aneurism by anastomosis of Bell. This form may originate some time after birth, or commence as a congenital small red spot—sometimes not larger than a pin's head—and increase rapidly and extensively until it involves the whole lid and extends upon the brow or cheek. It often pulsates, and is liable to dangerous, and even fatal, hemorrhage. It is enlarged by lowering the head, struggling, crying, or mental emotion. The cavernous nævus, or erectile tumor, consisting of spaces and sinuses filled with blood and separated by fibrous septa, has also been met with on the lids.

The treatment consists of excision; or the vessels may be obliterated by adhesive inflammation, coagulation, or ligature. Angiomata of moderate size can be safely excised by enclosing the part in a Snellen clamp and making the incisions in the sound skin. If the loss of substance is considerable, some form of blepharoplasty to restore the lid may be necessary. Small nævi may sometimes be successfully destroyed by the application of chemical caustics or the actual cautery. An efficient treatment is puncture by hot needles. Very large needles (shoemakers' awls have been used) heated in an alcohol lamp may suffice, but the application of the galvano-cautery in the form of fine platinum needles is better. In the case of infants, vaccination on the part has sometimes succeeded in exciting sufficient inflammation to occlude the vessels. The injection of coagulating fluids, tincture of chloride of iron, etc., is not without danger. Cases have been reported of death from heart clot or emboli. This danger may be reduced to a minimum by the use of the lid clamp, which should never be omitted. A safer way to cause coagulation is by electrolysis. Strangulation by ligature is an efficient, and in some cases the only available treatment. Serious results have sometimes occurred from the suppuration that follows, but these are rare. If the tumor is not too large, it may be included in a double ligature introduced under it by means of a large curved needle passed through the sound skin at its margins, and tied on each side. If a larger area must be included, this may be accomplished by the use of the Erichson ligature. (Fig. 245.) One-half of the thread is stained black with aseptic ink and the other half is left uncolored. All the white loops are cut on one side of the tumor and all the black loops on the other side, and the tumor is strangulated by drawing through and tying firmly each pair of white threads and each pair of black ones.

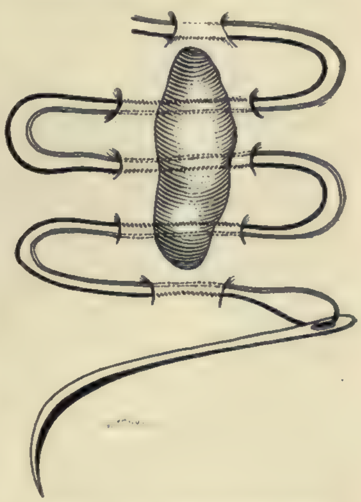


FIG. 245.—Erichson Ligature. (Gross.)

Lipoma.—The lids are normally devoid of fat, and lipoma is rare. It may occur between the muscle and the tarsus, or in front of the muscle and beneath the skin. It is soft and elastic and lobulated and is easily excised.

Fibroma.—Fibromata are developed in the deep layers of the skin or in the subcutaneous or submucous connective tissue. They may assume the appearance of plates of cartilage, or may form extensive pendulous tumors. They usually commence as small congenital tumors.

Neuroma.—The branches of the fifth nerve are not an uncommon seat of neuromata which may occur on the eyelids. They consist of degenerated nerves and hyperplastic connective tissue, and usually occur in association with similar tumors in other parts. They are nodules composed of tortuous cords which, when rolled under the fingers, give the impression of being soft. They are sensitive to touch, and sometimes very painful. Their origin is congenital. The only treatment is excision.

Elephantiasis.—A few cases of elephantiasis of the lids have been reported.*

Lymphangioma.—Lymphangioma of the eyelids has been met with in a few instances.† The tumor may extend into the orbit. There are always other symptoms of leukæmia.

Cysticercus Cellulosæ.—Cysticercus, appearing on the conjunctiva or in the orbit, may form a tumor of the lid. Sichel ‡ has reported a case in which the cysticercus was found between the skin and the tarsus.

Cyst of the Lower Lid, with Microphthalmos or Anophthalmos.—This is a congenital tumor of rare occurrence and obscure pathology. It is, properly speaking, an orbital cyst, but is known by the above title because it manifests itself in the lower lid. I have reported two cases in the Transactions of the American Ophthalmological Society in 1893 and 1902. In the former there was no trace of an eyeball; in the latter there was a rudimentary ball, scarcely larger than a pea. The lower lid was pushed forward by a large incompressible, but tensely fluctuating tumor, the blue color of which was evident through the thin and distended skin and gave, at first sight, the impression of an aneurism for which this tumor had been mistaken. (Fig. 246.)

Fig. 246.—Congenital Cyst of the Lower Lid, with Microphthalmos.

Most authorities agree that these cysts are formed of embryonic elements intended for the development of an eye, and are the result of an imperfect closure of the fœtal fissure; while a few insist that they have no necessary connection with the globe whose development is prevented by their presence.

Gangrene (Malignant Œdema).—A few cases of spontaneous gangrene of

* Wecker and Landolt, vol. i., p. 88.

† Dunn, Trans. College of Physicians of Phila., vol. xv., p. 103; Chauvel, Gaz. Hebdom., 23.

‡ Rev. Med.-Chir. de Paris, vol. i., p. 224.

the lids have been reported. The destruction of the skin is likely to necessitate a blepharoplastic operation.

Blepharospasm.—Spasm of the orbicularis varies from a slight twitching of a few fibres, scarcely noticeable by others than the patient, to a violent contraction of the whole muscle, which may close the eyes completely for several minutes at a time. The milder forms may be due to an irritation of the eye, or to a refractive or muscular strain, but are more frequently of a choreic character, particularly in children, and often occur in connection with spasm of other muscles of the face. Reflex irritation from the teeth or the accessory cavities of the nose is sometimes the cause. Curious cases of spasmodic twitching of the eyelids in association with movements of the jaw have been reported.* The most inveterate cases are those connected with trifacial neuralgia (*tic douloureux*). The spasm can be temporarily arrested in some cases by pressure upon the supraorbital or infraorbital nerve, or other "pressure points" in the course of the branches of the fifth.

In the treatment sources of reflex irritation should be looked for and removed, if found, and the refraction and muscle-balance should receive careful attention. The most efficient palliative remedy is the subcutaneous injection of morphia, but its dangers should not be forgotten. Tonics, fresh air, rest, etc., are needed in chronic cases. Arsenical preparations are often useful. Smoked glasses give relief to the photophobia. The constant current occasionally affords relief. In more violent cases exsection of portions of the orbicularis muscle, and section or exsection of the supraorbital or infraorbital nerve, may effect a cure, which, however, is too often temporary. Exsection of the trunk of the second branch of the fifth behind Merkel's ganglion and removal of the Gasserian ganglion have been practised, but these operations belong to general surgery. (See Dr. Frazier's article on page 379 of the present volume.) Section of the facial nerve with implantation of the peripheral end in the external branch of the spinal has been tried with some success.† Deep injections of alcohol at the point of emergence of the facial nerve have recently proven successful.‡ "The external ear was drawn upward and forward, the needle of a Pravaz syringe was inserted at the summit of the angle formed by the anterior border of the mastoid process and the cartilage of the meatus and pushed perpendicularly and slightly forward to a depth of 2 cm., when it impinged against the styloid process. The point was then directed a little backward and fell upon the facial nerve at its exit from the foramen, and a cubic centimetre of alcohol at 80° C. was injected. The pain may be diminished by the addition of cocaine or stovaine. Immediately after the operation there was severe but transient pain, and in a few minutes there was complete facial paralysis. This paralysis commenced to diminish in

* Harlan, The Ophthalmoscope, vol. ii., p. 177.

† Ophthalmology, July, 1905, p. 771.

‡ Annales d'Oculistique, Dec., 1905; Ophthalmology, July, 1906, p. 715.

a quarter of an hour, but did not disappear for some days. At the end of twenty days there was scarcely a trace of paralysis or spasm. Later, there was still further improvement and the patient resumed her work."

Fissure of the Canthus.—This lesion often occurs in connection with cases of ophthalmia accompanied by photophobia and orbicular spasm. The orbicular spasm forms a fold of the skin at the outer canthus, which becomes excoriated by the conjunctival discharge and acts as a cause of reflex irritation. Slight cases may often be cured by touching the part with the mitigated stick of silver nitrate, but others will require a free canthotomy, or, if the commissure is permanently narrowed, a canthoplasty. (See page 562.)

Sympathetic Spasm of the Eyelids ("von Graefe's Symptom").—This affection was described by von Graefe as a symptom in exophthalmic goitre.* The upper lid lags and does not freely follow the downward movement of the ball, and when the patient looks directly forward, there is a slight retraction of the lid leaving the sclerotic exposed above the cornea. It is attributed to spasm of Mueller's muscle controlled by the sympathetic. This symptom has been observed also in hysteria and in locomotor ataxia. Stellwag called attention to the fact that in exophthalmic goitre the act of winking is incomplete, irregular, and diminished in frequency. This is called the "Stellwag sign." These symptoms are usually met with in the earlier stages of the disease, but are not constant.

Paralysis of the Orbicularis (Lagophthalmos, or "Hare Eye").—This form of paralysis may be of peripheral or of central origin. In the former case the cause may be inflammation of the facial nerve from exposure of the face to cold draughts, direct traumatism, pressure by periorbital swelling or enlargement of the parotid gland, fracture of the temporal bone, or, most frequently, involvement of the nerve in middle-ear disease in its passage through the Fallopian canal. Paralysis of the facial nerve from intracranial cause is comparatively rare, and the orbicularis often escapes when the other muscles of the face are paralyzed. When occurring in connection with hemiplegia, the facial paralysis may be on the same side with it, or on the opposite side. When the lesion is in the anterior portion of the pons, or in front of it, the facial paralysis is on the same side with the hemiplegia; when it is in the posterior portion of the pons, or behind it, the facial paralysis is on the same side as the lesion and opposite to the hemiplegia. In the early stages of inflammatory cases leeches and hot stupes should be applied in front of the ear. Later, the constant current and injections of strychnia are recommended. The cornea should be protected by keeping the lids closed with plaster or compress, or, if the paralysis is permanent, tarsorrhaphy will be required. (See page 566.)

Ptosis.—Ptosis, or want of power to raise the upper lid, may be due to inflammatory swelling or accumulation of fat, tonic spasm of the orbicularis,

* Berlin. klin. Wochenschr., No. 31, 1867.

paralysis of the levator, or imperfect development of this muscle. It is sometimes congenital, and often the result of injury inflicted during delivery. It is sometimes hysterical. Transient ptosis, occurring in neurotic or enfeebled subjects, particularly in nursing women, consists in an inability to open the eye on awakening until the lid has been raised by the finger.* Simple failure of the lid to follow the motion of the ball when the eye looks upward is attributed to paralysis of Mueller's muscle, and occurs as a result of lesion of the sympathetic.† Ptosis from central lesions, or from syphilitic or rheumatic inflammation of the nerve, is frequently accompanied by paralysis of some of the ocular muscles supplied by the third nerve. Paralysis of the levator may be distinguished from spasm of the orbicularis by watching the fold above the upper margin of the lid while the patient makes an effort to open the eye. If there is no power in the levator, and the lid is raised entirely by the occipito-frontalis, this fold will be obliterated; if the levator acts at all, it will be deepened; or if the occipito-frontalis is prevented from acting by firm pressure with the hand, the lid will remain motionless.

In the treatment of paralytic ptosis medical means should first be tried. If it is of syphilitic or rheumatic origin, the appropriate remedies will be suggested. The constant current is sometimes of use. Operative interference should not be resorted to until it is evident that the condition is permanent, or not at all if it is likely that the diplopia resulting from associated paralysis of some of the muscles of the ball will be a greater misfortune than the ptosis. (See page 568.)

Ecchymosis.—Ecchymosis is an effusion of blood into the loose subcutaneous tissue of the lid, and is usually accompanied by more or less œdema. It is generally the result of rupture of blood-vessels by direct violence or by straining, as in violent paroxysms of coughing, but also occurs spontaneously by leakage from the degenerated blood-vessels of old people. It is sometimes a symptom of fracture of the base of the skull, when it is likely to appear some hours after the injury. Immediately after the injury, in traumatic cases, the application of ice or cloths wet with iced water, is the best means of checking the exudation. "Red oil," made from St. John's wort and sweet oil, was formerly a favorite domestic remedy and was sanctioned by high ophthalmological authority. Later, hot applications hasten the absorption of blood, as may also slightly stimulating embrocations, such as tincture of arnica, another much-lauded domestic remedy. In the spontaneous cases the ecchymosis is generally slight and may be left to nature.

Emphysema.—Emphysema is caused by a communication between the subcutaneous connective tissue and the neighboring air cavities, usually the result of fracture, but sometimes of destructive disease of the bone. It is sometimes a symptom of fracture of the base of the skull involving the orbit. It is easily

* Harlan, Annales d'Oculistique, January, 1877, p. 82.

† Harlan, Annals of Ophthalmology, April, 1901.

recognized by the crepitation felt when the skin is pinched between the fingers, and by the fact that the swelling is induced or increased by the patient's blowing his nose. Avoidance of the latter is usually the only treatment needed, but if the swelling is excessive, it may be relieved by puncture and pressure.

Wounds.—Wounds of the lids usually unite quickly on account of the vascularity of the part. They should be carefully freed from foreign bodies, and rendered aseptic by thorough washing with solution of boric acid, or of hyd. bichlor., 1:5,000, and the edges accurately brought together with fine stitches, even when they are lacerated. When the whole thickness of the lid is involved, if the margin is not kept well in line, there will be a disfiguring notch. To prevent this, a marginal suture, at the roots of the lashes, should be used. Iced cloths make an agreeable and useful application, or, if the patient is going about, a pad of absorbent cotton wet with a solution of bichloride, 1:5,000, and covered with oiled silk or waxed paper, may be bound upon the eye. The puncta and canaliculi should be preserved, if possible.

Injuries by burns and caustics often cause great mischief by the subsequent cicatricial contraction which may result in extensive ectropion or exposure of the ball. This may sometimes be prevented by an immediate tarsorrhaphy. (See page 566.)

Tarsitis.—The tarsus may be involved in inflammation extending from the skin, particularly in erysipelas, or in chronic and recurring eczema, but much more frequently it participates in disease of the palpebral conjunctiva, with which it is closely connected. The cicatricial contraction of the deep layer of the conjunctiva and the atrophy of the tarsus after trachoma are a frequent cause of distortion of the lid, with entropion and trichiasis. Uncomplicated tarsitis is comparatively rare and is nearly always of syphilitic origin. In some cases it has been considered tuberculous.* There is a uniform thickening of the lid, which appears hard and stiff and cartilaginous to the touch, while the skin is freely movable over it. Cases of amyloid degeneration following chronic tarsitis have been reported.†

The treatment of tarsitis is essentially medical. If of syphilitic origin it will almost certainly be cured by the administration of mercurials and iodides, to which the local application of mercurial ointment may be added. The rare cases of tuberculous origin will require the treatment applicable to tuberculosis. It is sometimes necessary to excise the cartilage, or a part of it.

Chalazion.—Chalazion is a small tumor of the tarsus resulting from inflammation of a Meibomian gland, with retention of the secretion, but is not strictly a retention tumor as was formerly thought. (Fig. 247.) It is smooth and rounded and rather hard, not often larger than a split pea or cherry stone, and usually smaller, firmly connected with the tarsus but freely movable under the skin. It contains a gelatinous mass of degenerated cells and, in the later stages, gran-

* Archives d'Ophthalmologie, June, 1905.

† Wecker and Landolt, vol. i., p. 133.

ulations and pus, enclosed in an imperfect capsule composed of condensed surrounding tissue. It usually progresses toward the conjunctiva, when it can be located on the everted lid by a patch of thinned mucous membrane of a bluish or yellowish color. In the last stage the conjunctiva sometimes gives way and allows the softened mass, mingled with pus, to escape; and granulations sprout through the fistulous opening. Chalazia are apt to be multiple and often occur in series. Small ones occasionally disappear spontaneously, or under the use of iodide or mercurial inunctions. The only effective treatment is removal (See page 561.)

FIG. 247.—Chalazion. (Dalrymple.)

Carcinoma; Sarcoma; Adenoma.—The Meibomian glands may also be the seat of carcinoma or sarcoma, though these diseases are rare in any part of the lids as primary affections. The lids may be involved, however, in growths originating in the orbit. In the early stages carcinoma or sarcoma may present a close resemblance to chalazion, as may also a gumma of the Meibomian glands. The former soon outgrow this resemblance, and the latter progresses toward the skin rather than toward the conjunctiva, and generally breaks down and forms an ulcer. Cases of adenoma of the Meibomian glands have been reported. Meibomian adenoma is of slow growth, and its limits are more sharply defined than those of chalazion in which there is inflammatory exudation in the surrounding tissue.

Calcareous Concretions.—These sometimes form in the Meibomian glands and, projecting from the conjunctiva, appear as little yellowish nodules on the inner surface of the lids. They may easily be pricked out with the point of a small knife.

Trichiasis.—Some or all of the lashes, as a result of cicatricial contraction of the lid margin and disease of the cilia bulbs, take a wrong direction and impinge upon the eyeball. Trichiasis is usually accompanied by more or less inversion of the lid margin from contraction of the conjunctiva. If there are not more than two or three lashes inverted, the patient's condition may be made bearable by pulling them out repeatedly with the cilia forceps.

A painful irritation of the eye is sometimes kept up by the presence of a fine, colorless lanuginous hair, scarcely visible without a lens and oblique illumination.

Distichiasis.—Distichiasis, which means a double row of lashes, can perhaps be applied with strict correctness only to a congenital condition. Some cases of trichiasis, however, in which about half the cilia are turned in upon the ball while the others retain their normal position, present this appearance and often receive the designation.

Entropion.—Entropion, or inversion of the lid margin, may be spasmodic or cicatricial, or due to relaxation and redundancy of the skin of the lid. The edge of the lid is turned inward, and the lashes are brought in contact with the eye. The spasmodic form, sometimes called "acute entropion," is due to spasm of the orbicularis muscle, usually the result of photophobia caused by inflammation of the conjunctiva and cornea. Cicatricial entropion is caused by contraction of the palpebral conjunctiva and distortion of the tarsus following chronic conjunctivitis, nearly always trachomatous. Inversion of the lower lid from relaxation of the skin and recession of the eyeball caused by the loss of fat in the orbit is not uncommon in old subjects, and is known as "senile entropion." A somewhat similar form, due to redundancy of the skin, is sometimes met with as a congenital condition.

Spasmodic entropion will usually disappear when the photophobia is relieved, but will often require a free canthotomy, or, if the condition returns, a canthoplasty. The cicatricial form can be cured only by operation and often with great difficulty. (See page 563.) Senile entropion may be relieved by the removal of a fold of the relaxed skin, or, as suggested by Dr. Theobald, by resorting to the obsolete treatment of the ancient Egyptians, who produced cicatricial contraction of the skin by the use of caustics in all forms of entropion. This is the most satisfactory treatment, and will generally be accepted by patients who would not consent to the use of the knife. Potash is the best caustic for the purpose. The stick may be brought to a point by rubbing it on wet blotting paper or absorbent cotton. An eschar should be produced 3 or 4 mm. wide and about 2 mm. from the lid margin and along its whole length. Excessive action may be checked by olive-oil or dilute vinegar or acetic acid, which may also be applied to the skin below the position of the caustic to prevent its spreading. The operation is not very painful, and no scar is discoverable after the lapse of a few weeks. Ziegler makes a series of galvano-cautery punctures near the lid margin. (*Oph. Record*, June, 1908.)

Ectropion.—Ectropion, or eversion of the lid margin, is often a result of cicatricial contraction of the skin following burns, wounds, or ulceration. A very troublesome form is caused by adhesion of cicatrices to the bone in caries of the orbital margin, or in fistula of the frontal sinus or antrum. Acute or spasmodic ectropion is caused by swelling of the conjunctiva and spasm of the orbicularis. It is common in children with phlyctenular ophthalmia. The bulging conjunctiva forces the lid margin outward, and contraction of the orbicularis maintains and increases the ectropion. Hypertrophy of the conjunctiva may render the condition permanent. Obstruction of the return circulation by tumors of the orbit or cavernous sinus is sometimes a cause. In senile ectropion the atrophied lower lid, with its enfeebled muscle, simply drops away from contact with the ball.

In the acute form the ectropion will generally disappear when the inflammation of the conjunctiva is relieved. Its disappearance may be hastened by freely slitting the chemosed conjunctiva with a pair of sharp-pointed scissors. The other forms will require operation. (See page 565.)

Epicanthus.—This consists of an excess of skin over the root of the nose between the eyes, a fold of which overhangs the inner canthi. It is generally associated with a depression in the bone at the root of the nose. Milder forms of it existing in children may disappear as the bone develops, but others re-require operation. (See page 570.)

Ankyloblepharon.—Ankyloblepharon is an adhesion of the edges of the lids to each other. It usually results from excoriation of the lid margins by burns or caustics. It has occasionally been met with as a congenital condition. It is usually complicated with symblepharon. (See page 567.)

Blepharophimosis.—Blepharophimosis is a contraction of the palpebral commissure. It may be a partial ankyloblepharon limited to the outer canthus and due to excoriation of the canthus by long-continued conjunctivitis; or the commissure may be shortened and narrowed by the cicatricial contraction following trachoma. It frequently complicates entropion and blepharospasm. The lid margins injure the cornea by pressure. Blepharophimosis is remedied by canthoplasty. (See page 562.)

II. OPERATIONS UPON THE EYELIDS.

Operations for Chalazion.—When the tumor is of moderate size and presents itself toward the conjunctiva, which is usually the case, it is opened by a free incision, made perpendicular to the length of the lid to avoid injury to neighboring glands and inversion of the lid by cicatricial contraction. The contents are removed by a scoop (Fig. 248), with which the capsule is scraped to excite adhesive inflammation of its walls. The lid may be held in the inverted position on the end of a horn spatula, or the flat handle of a silver probe, against which the incision is made. Only local anæsthesia by cocaine is generally required. If the tumor is larger and just under the skin, it should be dissected out with a small scalpel or Beer's cataract knife and a small pair of sharp-pointed scissors. The lid is held firmly, and hemorrhage is prevented by means of a Desmarres or Snellen lid clamp. Care should be taken not to buttonhole the conjunctiva, which, however, cannot always be avoided. The operation is quite painful, and may require general anæsthesia.

FIG. 248.—Chalazion Scoop.

Canthotomy.—This is a mere slitting of the external canthus. It is a very simple operation and temporary in its effects, but is often extremely useful. The lids are separated and the canthus put upon the stretch by a spring speculum, and the conjunctiva, muscle, ligament, and skin are cut through with a strong pair of blunt scissors pushed well against the outer margin of the orbit; or the cut may be made with a bistoury passed along a grooved director placed beneath the canthus.

Canthoplasty.—If a more permanent effect is required, after canthotomy the incision may be prevented from closing by uniting the cut edges of the conjunctiva and skin with sutures. Three are usually enough—one at each margin and one at the angle. (Fig. 249.) The edge of conjunctiva is taken up with forceps while the stitch is passed.

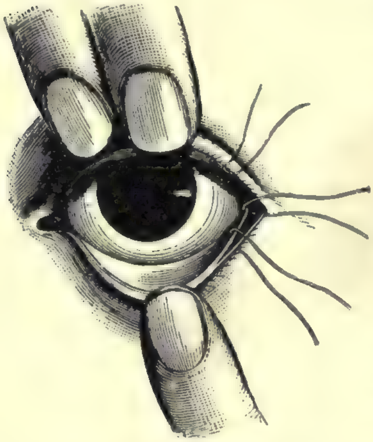


FIG. 249.—Canthoplasty. (Meyer.)

Operations for Trichiasis.—Various means have been resorted to to prevent the extracted cilia from growing again by destroying the bulbs. Celsus introduced a red-hot, broad, thin needle into the bulb. Steel needles dipped into fused nitrate of silver have been used. The best means is by electrolysis. (Michel.) A fine platinum needle connected with the negative pole of a battery is inserted by the side of a lash into the bulb, and the circuit is closed by placing the positive electrode, covered with a wet sponge, on the patient's temple. Bubbles of hydrogen appear and the loosened lash falls out, or is easily removed.

Many cases are associated with entropion and are treated by operations performed to correct it. In desperate cases, when the lashes are reduced to a few stubby hairs pointing in all directions, and the lid margin is converted into a rounded cicatrix, the operation of "scalping" may serve to get rid of the cilia entirely. The lid margin is split, as in the Arlt operation for entropion (Fig. 252), and then, while the lid is held on a horn spatula applied to its conjunctival surface, an incision is made through the skin and muscle down to the tarsus, 2 or 3 mm. from the lid margin and parallel to it, and a strip of tissue, containing the skin muscle and cilia bulbs, is removed with scissors. Care must be taken that no bulbs remain to grow new lashes. They can be seen, with a magnifying lens, as small black specks, and removed with forceps and sharp-pointed scissors, or destroyed with a point of silver nitrate. The edges of the skin and conjunctiva are brought together with sutures.

An operation recently much resorted to is the transplantation of a graft in the lid margin behind the line of the lashes. The edge of the lid is split deeply enough to make a gaping wound 2 mm. wide (Fig. 252), and a strip of skin the length of this incision, 2 or 3 mm. wide at its middle and tapering toward the ends, is taken from behind the ear and pressed into the cut, where it is held without stitches by atmospheric pressure and a retaining compress. Or the flap of skin may be taken from the lid, if it is desired at the same time to evert the lid margin. Some operators prefer a Thiersch graft, and Van Millingen, who originated this method of operating, uses a strip of mucous membrane taken from the inner surface of the lower lip. The parts are dusted with iodoform and covered with iodoform or boric-acid ointment spread on gauze, and a pad of absorbent cotton is applied and held in place by a retaining bandage, which is left undisturbed for three or four days.

FIG. 250.—Green's Entropion Operation.

Operations for Entropion.—The object of entropion operations is to evert the lid margin. This may be done by removing a flap of the skin of the lid and suturing the edges of the wound, but in cicatricial cases, which depend upon contraction of the conjunctiva and tarsus, the effect is likely to be temporary, and nothing done to the skin alone will often result in a permanent cure. John Green, of St. Louis, makes an incision in the under surface of the lid parallel to the margin and 2 mm. above it (upper lid), and carried through the entire thickness of the tarsus. A strip of skin 2 mm. in width and $1\frac{1}{2}$ mm. above the line of the lashes is then removed. Sutures are introduced at the conjunctival side of the lashes, brought out just within the wound in the skin, introduced at the upper margin of the wound, passed deeply upward, grazing the tarsus, and brought out through the skin a centimetre or more above the points of entrance. When these sutures are tied, the skin wound is closed and the loosened lid margin is everted. (Fig. 250.)

In a number of cases I have operated satisfactorily in a somewhat similar manner, except that, instead of incising the cartilage, I split the edge of the lid (Arlt) just behind the lashes. (Fig. 252.) Then a strip of skin 4 mm. wide, parallel to the lid margin and 4 mm. above it, is removed and a narrow band of muscular fibres is dissected out at the upper margin of the wound. Sutures are passed through the posterior lip of the split margin, over the roots of the lashes, under the muscle at the upper edge of the wound, and brought out through the skin 5 or 6 mm. above the last point of entrance. When they are tied, the strip containing the cilia is strongly tilted forward and its cut edge is crowded into the groove in the muscle, while the edge of the tarsus is drawn downward. (Fig. 251.)

FIG. 251. — Entropion Operation of Harlan.

Arlt's operation, which is the basis of several others, consists of splitting the edge of the lid into two layers, the anterior containing the skin, muscle, and cilia, and the posterior the tarsus and conjunctiva, and everting the edge of the anterior layer by removing a flap of skin from the lid 3 or 4 mm. above the margin and suturing the edges of the wound. (Fig. 252.)

One of the most rational operations is the Hotz-Anagnostakis. Anagnostakis, in 1857, conceived the idea of uniting the skin to the upper margin of the tarsal cartilage, and described an operation designed to accomplish this. When, by the old operation, a flap of skin is removed and the edges of the wound are sutured there is no firm attachment. The skin is freely movable, and when the lid is raised the effect of the operation is much diminished. But the tarsus offers a firm point of attachment and carries the lid margin with it when it is raised. The operation, however, was not adopted, and was entirely forgotten, when Dr. Hotz, without knowledge of it, twenty years later described an operation based on the same principle. An incision of the skin is made along the upper margin of the tarsus, which is defined by a fine furrow in the skin extending from canthus to canthus. While an assistant fixes the skin against the supraorbital margin, the centre of the free edge of the lid is seized between the forefinger and thumb, or in a pair of forceps, and drawn downward until the convex furrow is changed to a horizontal line. An incision through the skin is made along this line, extending from a point 2 mm. above the internal canthus to a corresponding point above the external canthus. This incision is changed to a gaping wound by the retraction of its upper border. The upper margin of the tarsus (upper lid) is exposed by removing, with scissors, a strip of the orbicularis muscle along the lower border of the wound. It can be recognized by its yellowish color and tendinous appearance, in contrast to the dark red of the orbital tissue. Four sutures are usually sufficient. They are passed through the skin at the lower edge of the wound, the upper third of the tarsus, the tarso-orbital fascia, and the upper margin of the wound, and firmly tied. They are removed on the third day. (Fig. 253.)

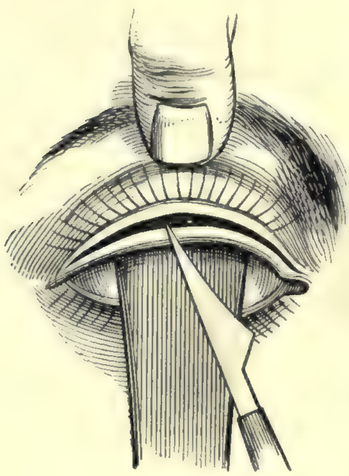


Fig. 252.—Arlt's Operation.

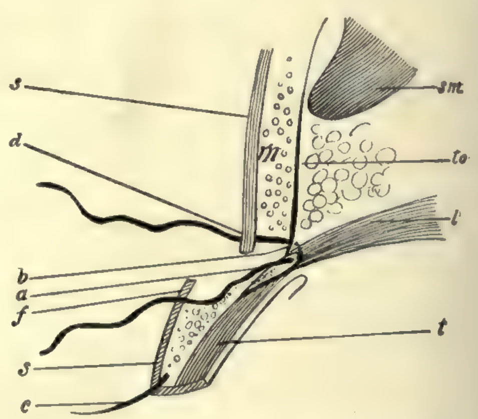


Fig. 253.—Vertical Section of the Eyelid. *sm*, Bony supraorbital margin; *to*, tarso-orbital fascia; *l*, tendon of the levator muscle; *t*, tarsus; *m*, orbicularis muscle; *e*, eyelash; *s*, skin; *d*, upper border of wound; *f*, lower border of wound; *a*, *b*, course followed by suture. (Hotz.)

Dr. Hotz has since recommended, in some cases, to combine the intermarginal graft (see Trichiasis) with this operation. When the commissure is contracted, a canthoplasty will be of use.

Operations for Ectropion.—When ectropion is due to simple inflammatory swelling of the conjunctiva, it may often be relieved by freely slitting the latter with a pair of sharp-pointed scissors, entering one blade at the outer canthus and passing it to the inner. If hypertrophy of the conjunctiva has made the condition permanent, a fold of the conjunctiva should be excised. When ectropion

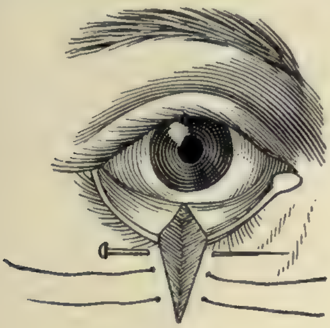


Fig. 254.

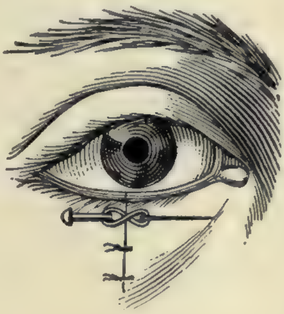


Fig. 255.

Figs. 254 and 255.—The Adams Ectropion Operation. Fig. 254 shows wedge-shaped piece removed from lower lid; Fig. 255, edges of wound brought together and lid margin in place.

is caused by relaxation of the lid and elongation of its margin, a wedge-shaped piece of the latter is removed and the edges of the wound are brought together with sutures, or with a small hare-lip pin. (Figs. 254 and 255.) The cosmetic effect is better if the piece of skin removed is at the external canthus. When there little or no elongation of the lid margin, the lid may be very neatly replaced by an operation suggested by Dieffenbach. An incision is made through the skin

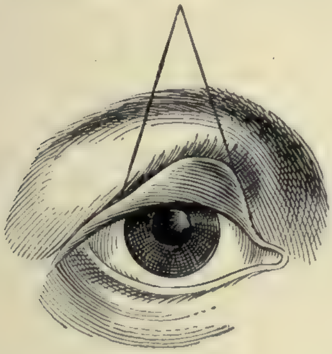


Fig. 256.

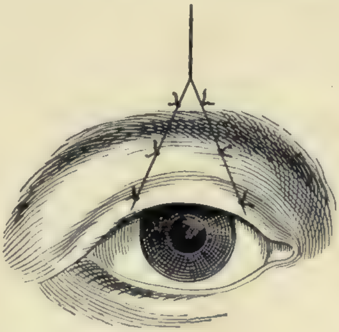


Fig. 257.

Figs. 256 and 257.—Ectropion Operation of Wharton Jones. Fig. 256 shows the lines of the incision; Fig. 257, the operation completed.

just above the lower margin of the orbit (lower lid) and the muscular fibres are separated or excised until the conjunctival fold is reached. This is then slit, and the anterior margin of the incision in the conjunctiva is seized with forceps, drawn into the wound in the skin, and sutured with it.

Ectropion from cicatricial contraction of the skin due to burns, etc., is more difficult to manage. When only a part of the lid is involved in the cicatrix, the operation of Wharton Jones is often successful. A V-shaped incision including the skin of the everted portion is made with its base at the lid margin. The flap thus marked out is dissected up to the roots of the lashes and the lid is replaced in its proper position, or a little beyond it, and held there by sutures. The space left bare is covered by undermining the skin and bringing the edges together with stitches. (Figs. 256 and 257.) This is applicable to either lid. When the whole skin of the lid is destroyed or reduced to a narrow cicatrix, some form of blepharoplasty will be required.

Operations for Ankyloblepharon.—Ankyloblepharon unaccompanied by symblepharon is usually relieved by a simple incision, if the canthus is not involved. If the canthus is involved, a canthoplasty will be needed to prevent re-adhesion of the lid margins.

Tarsorrhaphy.—Tarsorrhaphy is the artificial production of ankyloblepharon. If it is required to shorten the palpebral commissure by uniting the lid margins at the outer canthus, it is performed by placing a horn spatula beneath the canthus and cutting down upon it by two incisions which remove the lid margins and cilia bulbs and meet beyond the canthus, and suturing together the two freshened edges. If required for temporary purposes, as to protect the eye in cases of orbicular paralysis or to prevent retraction in operations upon or injuries of the lids, it is necessary only to unite a small space at the middle of the lid margins. The inner angle of the lid margins is removed, for about a quarter of an inch, with a small pair of scissors, and the two raw surfaces are brought in apposition by sutures. The sutures should be placed deeply through the whole thickness of the lid, to bring the freshened surfaces well together. This can be done by transfixing the lids $1\frac{1}{2}$ mm. beyond the lashes with two needles attached to one thread, drawing the thread through, and tying the two ends. The stitches are left in until firm union is established. The constant movement of the lids stretches the adhesion into a band, on each side of

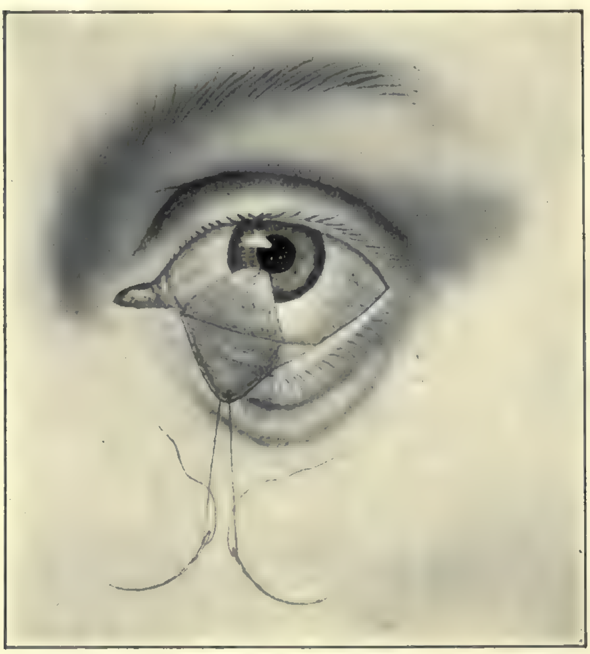


FIG. 258.—Arlt Symblepharon Operation. The drawing shows the adhesion dissected.

which there is useful vision. The canthus should never be included in the ankyloblepharon, if it is likely that a future freeing of the lids may be desired.

Operations for Symblepharon.—Symblepharon, if partial and not involving the cul-de-sac, is comparatively easy to manage, but total symblepharon offers a difficult and sometimes unsolvable problem on account of the persistence with which the cut surfaces reunite and form cicatrical contractions worse than before. In partial symblepharon, if the adhesion has been stretched into a band, which frequently happens, the best proceeding is that of Arlt. The band is dissected up from the ball (lower lid), and a thread armed with two needles is passed through its extremity. The needles are then passed through the conjunctiva and skin far back in the cul-de-sac, and the threads are tied together on the skin over a small roll of plaster. The raw surface of the band is thus turned in and applied to the lid, while its sound surface presents itself toward the ball. (Figs. 258 and 259.)

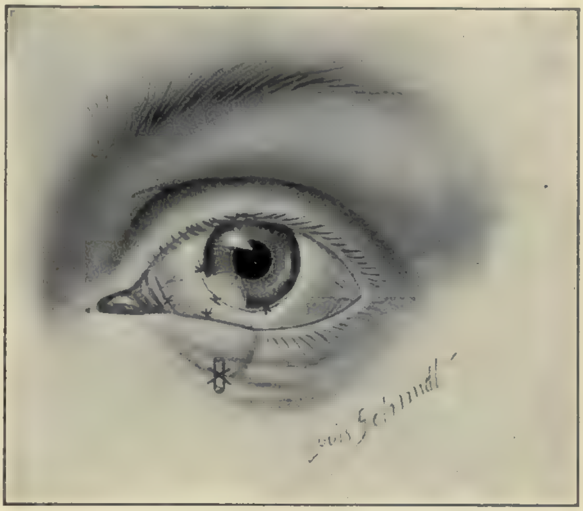


FIG. 259.—Arlt Symblepharon Operation Completed

The bare surface on the ball is covered by stretching the cut edges of the conjunctiva—freeing them, if necessary, by undermining the conjunctiva with scissors—or by transplanting sound conjunctiva from the upper part of the ball. (Teale.)

In cases in which the adhesions are closer and more extensive, involving, perhaps, the whole conjunctival surface of the lids, various attempts have been made to transplant flaps with pedicles from the neighboring skin, but with doubtful success. A great advance in the treatment of these cases has been made by the use of Thiersch grafts. May suggested holding these grafts in position by means of a prothesis shell (artificial eye), and Hotz used a disc of lead, ½ mm. thick, fitted into the conjunctival cul-de-sac. Hotz proceeds as follows (*Annals of Ophthalmology*, July, 1905): In the case of a symblepharon firmly uniting the lower lid and the eyeball, the lid was first separated from the ball by free dissection down to the position of the cul-de-sac. A half-moon-shaped disc (Fig. 260) of lead, with its angles rounded and with perforations along its straight edge, was formed. It was trimmed to fit the inner surface of the lid,

FIG. 260.—Lead Disc Used in Symblepharon Operation.

its convex edge resting in the cul-de-sac and its straight edge even with the lid margins. A large Thiersch graft was taken from the arm, transferred directly from the razor to the wound, and spread over the bulbar and the lid surfaces. A few fine sutures fastened it to the edge of the conjunctival wound on the ball, and the convex edge of the lead disc was placed over it and pressed down to the cul-de-sac. Care was taken that the graft should fit smoothly and there should be no rolling of the edges. Three sutures were passed through the edge of the graft, the holes in the disc, and the lid margin, and tied. A compress and a bandage were placed over the closed lids for two or three days, and the plate was allowed to remain in place a week.

In symblepharon of the upper lid, or of both lids, a disc of lead shaped like a prothesis shell, covering the whole front of the eyeball and with its upper edge in the upper cul-de-sac and its lower edge in the lower cul-de-sac, is used. If the cornea is sound, a hole may be cut in the disc to prevent injury by pressure or friction. The lid, or each lid, is covered with the graft, which is held in place by inserting the disc, and the free margins of the lids are united by strong sutures. These lid sutures generally hold for three or four days, and the disc is left in place for a week or more. Cases in which, after enucleation, cicatricial contractions in the orbit prevent the wearing of an artificial eye, may be operated on in a similar way.

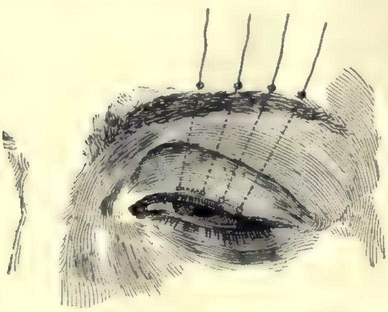


FIG. 261.—Thread Operation for Ptosis.

Operations for Ptosis.—If the levator is congenitally absent or completely paralyzed, the object of the usual operative procedures is to assist the occipito-frontalis to raise the lid. The simplest, but not the most efficient, way of accomplishing this is to remove a large flap of skin from the lid and unite the margins of the wound. Pagenstecher formed subcutaneous cicatricial tendinous bands, connecting the lid with the occipito-frontalis by means of threads. A strong silk thread is armed with two long needles. One needle is inserted in the skin just above the lid margin, passed horizontally under it for a distance of 2 or 3 mm., brought out, reinserted through the second opening, and passed under the skin to emerge above the eyebrow. The other needle is entered at the first opening and carried underneath the skin to emerge near the first. The two ends of the thread are drawn up sufficiently to place the lid in proper position, and tied together over a small roll of plaster. Several such threads may be used. (Fig. 261.) The thread may be removed when sufficient inflammation has been excited; or it may be drawn upon from time to time and retied until it cuts its way through the subcutaneous tissue and comes out at the brow, leaving a cicatrix in its track. Panas and Tansley produced the same effect more strongly by passing a tongue of skin from the lid beneath the brow. Tansley, whose operation is the less complicated, proceeds as follows: Two perpendicular cuts, *a b* and *c d*, parallel to each other and about one-fourth inch apart, are made through the skin from the upper margin of the orbit to within an eighth of an inch of the lid margin. (Fig. 262.) These cuts are united by a horizontal incision at the top, *a c*, and the tongue of skin thus marked out is dissected up and allowed to drop. Then horizontal cuts, *b h* and *d f*, are made from the base of the flap on each side to a point above the canthus, and a curved cut, *h g e f*, along the upper border of the tarsus, and the flap of skin and muscle is removed, leaving the tarsus bare. A long narrow knife (Graefe cataract knife) is entered beneath the skin at the upper extremity of the bared space (Fig. 263) and the point brought out above the brow, and a subcutaneous incision is made wide enough to admit the tongue of skin. This is drawn into the wound and sutured

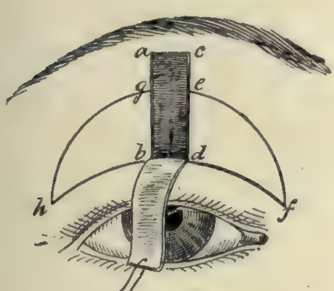


FIG. 262.

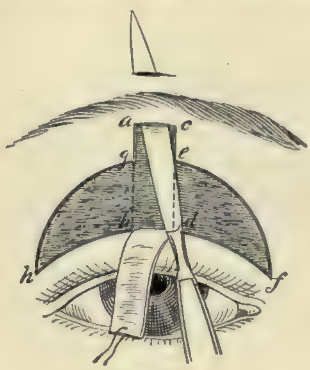


FIG. 263.

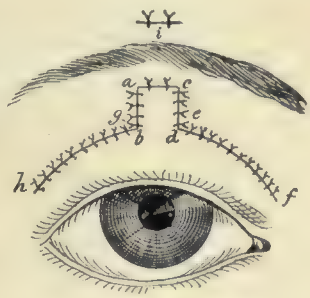


FIG. 264.

FIGS. 262 to 264.—Ptosis Operation of Tansley. Fig. 262, tongue of skin *acbd* dissected free down to base *bd*. Flaps *hbg* and *fde* are to be removed. Fig. 263, incision beneath eyebrow at *ac*. Flaps have been removed from shaded space. Fig. 264, operation completed.

with its end at *i*. (Fig. 264.) The edges of the wound on the lid are also sutured. The base of the flap *h b d f* should be nearer the lid margin than is represented in the figure.

A simple operation devised by Grandmont is one of the most satisfactory. He narrows the lid by removing a piece, not only of the skin and muscle, but also of the cartilage. While the patient looks directly forward, the distance from the supraorbital margin to the edge of the lid in each eye is measured, and the difference between them indicates the degree of narrowing of the affected lid required. A horn spatula is placed beneath the lid, or it is held in a Snellen clamp with a horn plate, and a semilunar flap of skin parallel to the lid margin and over the middle of the cartilage is removed, and the muscle is dissected away until the tarsus is exposed. Then a strip of the tarsus of the required width at the middle and tapering toward the ends is removed, by cutting down upon the spatula, and the edges are brought together by fine catgut sutures. The wound in the skin is closed by fine silk sutures, which may be removed on the third day, or the wound is allowed to heal by granulation.

Motais has used the superior rectus of the ball to assist in raising the lid in ptosis. A strip is freed from the middle of its tendon and is inserted between the tarsus and the skin of the upper lid, where it is sutured. The vertical diplopia that may result from the operation is said to disappear in a few weeks, but there would seem to be danger of disturbing the delicately adjusted co-ordination of the associated movements of the eyes.

Operations for Epicanthus.—von Ammon pinched up the skin between the forefinger and thumb to determine the amount to be removed, marked it with a pen or scalpel, cut out a vertical, elliptical fold, and brought the edges of the wound together with stitches or a harelip pin. Undermining the skin will facilitate the approximation of its edges. The objection to the operation is the more or less disfiguring vertical cicatrix that it leaves. Arlt endeavored to avoid this by removing a rhomboidal flap of skin with its long axis vertical, and suturing the wound horizontally.

Wecker pinches up the fold as in the von Ammon operation, passes threaded

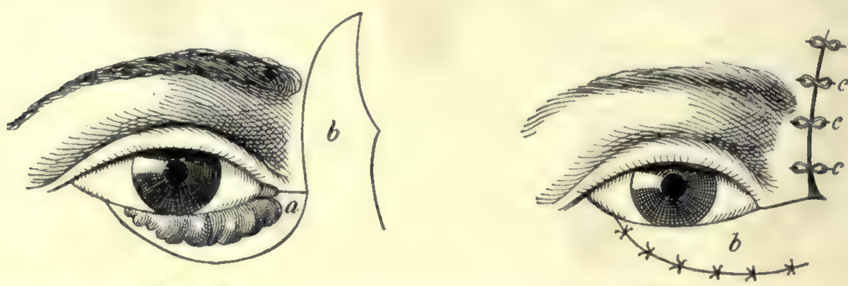


Fig. 265. Fig. 266.

Figs. 265 and 266.—Illustrating Tongue-flap Operation of Fricke. (Hasner.) Fig. 265 shows lines of incision. Flap *a* is to be removed, and flap *b* transplanted to its place. Fig. 266, operation completed.

needles through its base and excises it, and then draws the needles through and ties the threads. Knapp, to prevent subsequent puckering of the skin, undermines the edges of the wound freely and unites them with numerous fine stitches.

Blepharoplasty.—Blepharoplastic operations are often required for the restoration of the lids after their destruction by inflammatory sloughing, burns, or caustics, or traumatic injuries, or after the removal of epitheliomata or other tumors. Blepharoplastic operations by means of flaps with attachments, taken from the neighboring skin, are usually modifications of the tongue flap of Fricke or the rectangular sliding flap of Dieffenbach, and their form depends upon the requirements of the case and the ingenuity of the operator.

Figs. 265 and 266 give an idea of the principle of the former method. The diseased tissue is removed with the flap *a* and replaced by dissecting up and transplanting the flap *b*.

Figs. 267 and 268 illustrate an operation performed on a patient at the Wills' Hospital. The whole of the skin of the upper lid had been destroyed by sloughing, and the subsequent cicatricial contraction had drawn the lid margin to the edge of the orbit—causing extreme ectropion. The lid margin was dissected free from the cicatrix and drawn down, and the wide gap thus left was filled by transplanting a tongue flap from the temple and forehead. The space

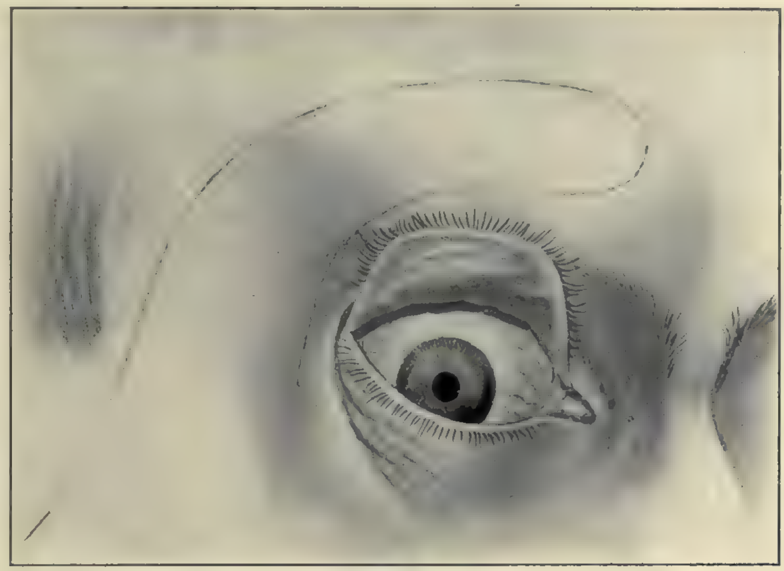


Fig. 267.

Fig. 268.

Figs. 267 and 268.—Restoration of Lid by the Fricke Flap. (Harlan.) Fig. 267, everted upper lid and outline of flap. Fig. 268, operation completed

from which the flap was taken was left to granulate. The apex of the flap threatened to slough, but was saved by the continuous application of dry heat. The levator palpebræ muscle had fortunately escaped injury, and when the patient was seen many years afterward there was scarcely perceptible deformity.

As a rule, the *Dieffenbach mode* is more satisfactory, when the conditions of the case admit of its use, as the vitality of the broad rectangular flap is better maintained. Fig. 269 (solid lines) shows the original form described by Dieffenbach. The diseased part is removed with the triangular flap *a b c*, and the bared space is covered by dissecting up and sliding over the rectangular flap *b c d e*, so that *c* is brought to *a* and *d* to *c*, and the space from which it has been removed is left to heal by granulation, after being narrowed as much as possible by freely undermining its edges and drawing them together with stitches at the angles.

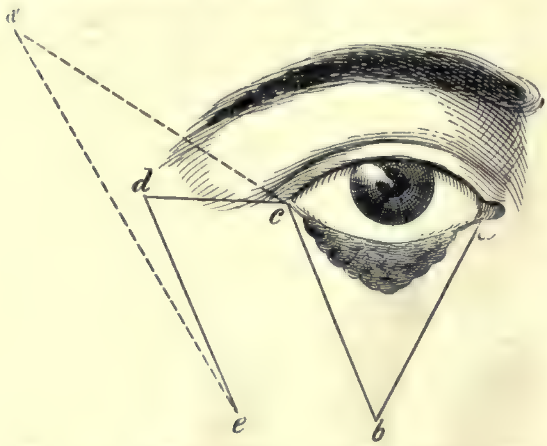


FIG. 269.—Dieffenbach Blepharoplasty. (Harlan.) The flap *abc*, containing the diseased tissue, is removed. The flap *edcb* is dissected free as far as to its base *eb* and transplanted to the bared space. The interrupted lines show the incisions in Szymanowski's modification of the operation.

A defect in the Dieffenbach operation (lower lid) is that the cicatricial contraction of the bared space tends to draw down the outer canthus and stretch the lid (Fig. 270). This tendency may be somewhat diminished by skin-grafting, or by transplanting a flap of thin skin (LeFort-Wolf) or a Thiersch flap from a distant part, usually the inner side of the arm or thigh. Szymanowski, instead of making the incision *c d* (Fig. 269) horizontal, carries it up and out to *d'*, thus giving a fuller flap and less downward contraction.

FIG. 270.—Condition of the Parts Nine Months after the Dieffenbach Operation. (Harlan.)

In a case of epithelioma involving nearly the whole of the lower lid, I filled the bared space from which the flap was taken by another sliding flap from the temple (Figs. 271, 272, and 273), leaving the granulating surface smaller and above the canthus. The space *c d e* (Fig. 272) left bare by sliding the flap *b a c e* (Fig. 271) was partly covered by sliding the flap *d c f g* from the temple, leaving a much smaller wound and one which does not tend to draw the canthus downward. (Figs. 274 and 275.)

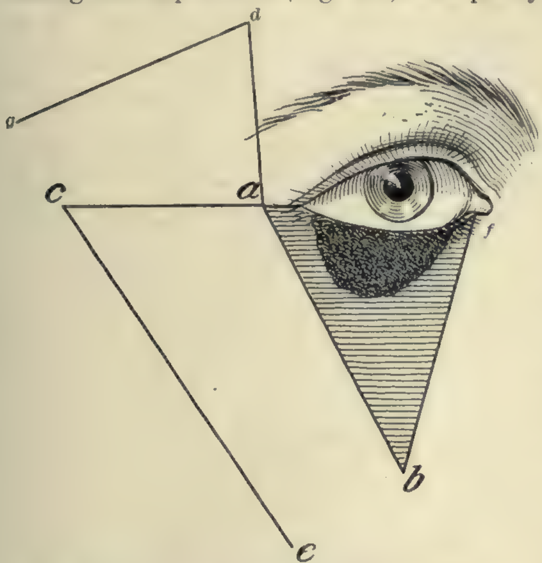


FIG. 271.—Lines of Incision in Modified Dieffenbach Operation. (Harlan.) The flap *abf* is removed. The flap *ecab* is dissected free down to its base *eb* and transplanted to *abf*. The flap *cadg* is dissected free as far as to its base *cg* and used to fill a part of the space left bare.

In a case of extensive epithelioma at the inner canthus, in which a large scar on the side of the nose, due to cauterization and previous operation, rendered it impossible to take a flap from that region, I operated by the Dieffenbach method as shown in Figs. 276 and 277. The diseased tissue was extirpated by the incisions *a c*, *c a′*, *a′h*, *h f* through the sound skin, and the bared space was covered by sliding a flap from the brow and forehead. The triangular piece of skin *a b c* was removed, the incision *e d* was made through the skin of the temple, and its lower extremity was connected with *a* by an incision through the skin of the lid, just above the lid

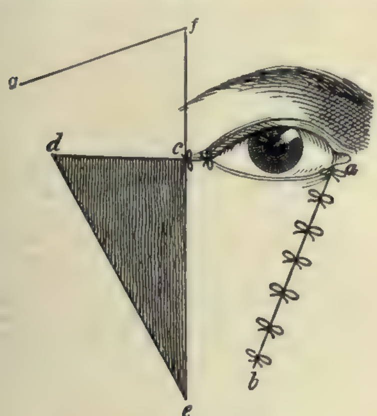


FIG. 272.

FIG. 273.

FIGS. 272 and 273.—Modification of Dieffenbach's Operation Completed. (Harlan.) Fig. 272, flap *ecab* is now in a new position, leaving *edc* bared. Fig. 273, flap *dcfg* is transplanted to upper part of the bared space. The margins of the lower angle of the bared space are undermined and brought together at *ce*.

margin, and the flap *e d a b* was dissected up to its base *e b*. Then, by a sliding movement, *a* was brought to *a′* and *d* to *d′*. (Fig. 277.) The lower lid was freed by an incsioni $h\ g$ through the skin of the cheek, undermined and drawn up to be stitched to the upper flap at a' and f'. The space $e\ d\ d'$ was left to granulate.

FIG. 274.—Condition of the Parts Three Years after Modified Dieffenbach Operation. (Harlan.)

Knapp removed the diseased tissue with a quadrangular piece of skin and covered the bared spaces by dissecting up an extensive long flap and sliding it, by stretching, as illustrated in Figs. 278 and 279. If necessary, such a flap can be met by another from the opposite side. The base of the flap should be considerably wider than its extremity to insure a free blood supply.

Hasner used sliding flaps with curved margins as shown in Figs. 280 and 281. The points of the flaps were cut off at h and i (dotted lines).

The Tagliacotian method of transplanting a flap from a distant part and retaining a pedicle temporarily has been tried in a few cases. The flap is taken from the arm, which is kept bandaged to the head for some days

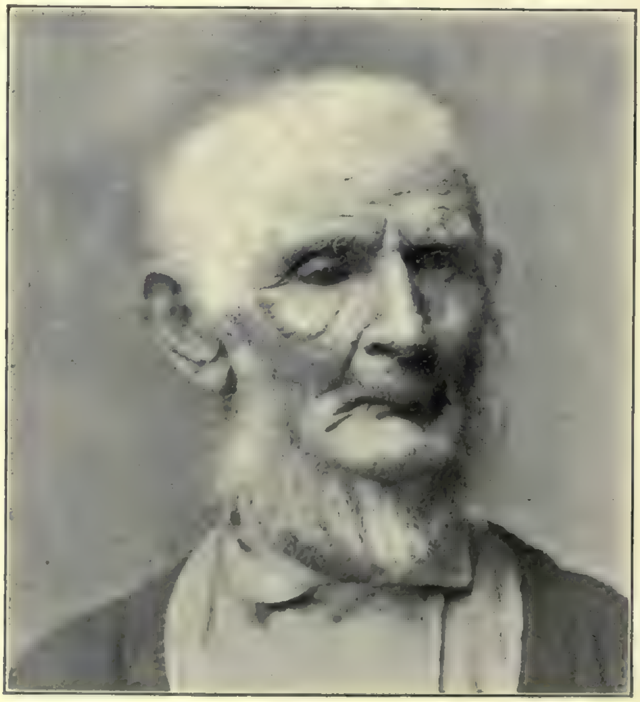


FIG. 275.—Condition of the Parts Two Months after Modified Dieffenbach Operation. (Norris.)

until the flap unites, when the pedicle is cut (R. H. Derby, Trans. Am. Oph. Soc., 1885).

This operation is tedious and painful, and the suffering caused by maintaining the constrained position for many days is serious. It is of course recommended only in cases in which it is not possible to secure a flap from the neighboring skin. As a substitute in such cases, Snydacker, of Chicago, has described an operation (*Monatsblaetter für Augenheilkunde,* 1907, p. 71) in which the flap is taken from the neck. (Fig. 281, *a.*) A long flap is dissected from the neck, in the line of the sterno-cleido-mastoid muscle, with its base below and a little behind the lobe of the ear, and its other extremities in the region of the clavicle. It

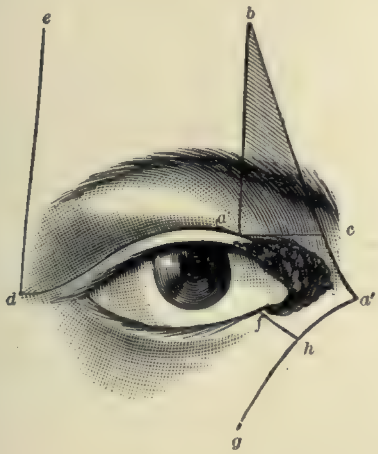


Fig. 276.

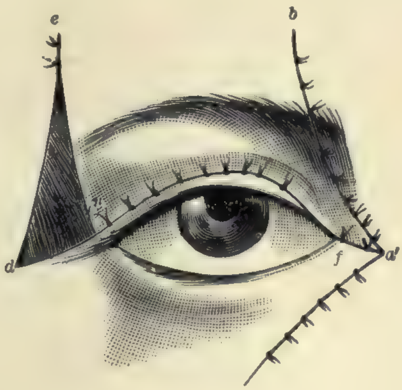


Fig. 277.

Figs. 276 and 277. Removal of Growth at Inner Canthus. (Harlan.) Fig. 276, tissue within the area *aba′gf* is removed. Flap *edab* is dissected free as far as to base *eb,* and is extended until *a* is brought to *a′*. Flap *cgf* is also dissected free, and *g* is brought to *a′*. Fig. 277, operation completed, *edd′* being left to granulate.

should, of course, be wider than the space which is to be covered, to allow for contraction. The skin of the neck, being loose and distensible, can be brought together after the removal of a strip 5 or 6 cm. in width. The free extremity of this flap is applied to the bared space and stitched in place, while the bridge between this extremity and the base lies upon the sound skin of the cheek. When the flap has united,—perhaps in ten days or two weeks,—this bridge is cut away.

Morax (*Annales d'oculistique,* January, 1908) has recently used the bridge as an additional flap in case of extensive destruction of tissue. It must, of course, be fastened when used in this way.

The Le Fort method of transplanting a flap without a pedicle (brought to the attention of English surgeons by Wolfe) has been frequently resorted to. The flap should be very thin, freed from fat and subcutaneous tissue, and a third or a half larger than the space to be covered, to allow for subsequent contraction. The immediate contraction is considerable, and a flap cut one-third larger than the space will generally be found not too large to fit in without wrinkling. The region of the operation and the skin to be transplanted should be made

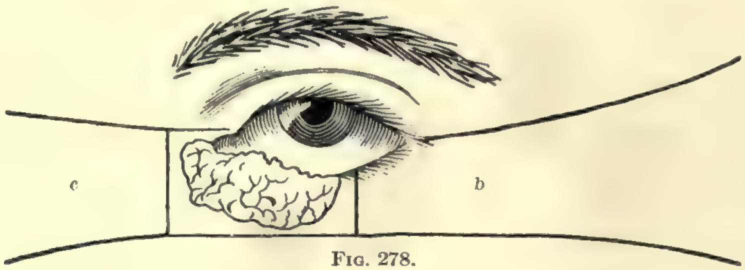


FIG. 278.

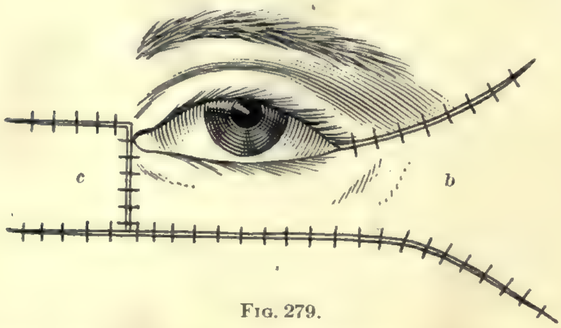


FIG. 279.

FIGS. 278 and 279. Knapp's Blepharoplasty by Rectangular Flaps. Fig. 278, the diseased area *a* is exsected; the flaps *b* and *c* are freed and their ends are brought together by stretching. Fig. 279, operation completed.

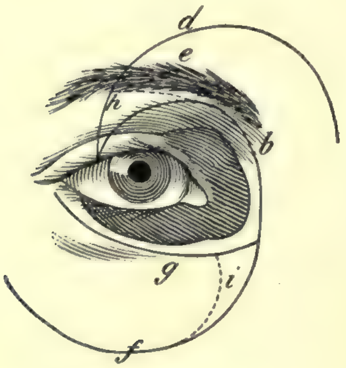


FIG. 280.

FIG. 281.

FIGS. 280 and 281. Hasner's Blepharoplasty. Fig. 280 shows the diseased area and the lines of the incisions. The points of the flaps were cut off along the dotted lines. Fig. 281 shows the operation completed. Gaps are left at two points, *d* and *e*.

thoroughly aseptic by washing with soap and then applying freely ether or alcohol and afterward bichloride solution. The lid is placed in position, after dissecting it free from the cicatricial tissue or removing the growth, as the case may be, and its margin is united by tarsorrhaphy to that of the sound lid. The surface of the wound, which is prepared first, is freed from cicatricial tissue and clots, and the hemorrhage is checked by pinching bleeding points with forceps and applying hot water and pressure with absorbent cotton, and the region is covered with gauze wet with sterile salt solution (1 to 6,000) while the flap is being cut. This is laid across the forefinger while it is carefully freed from fat and subcutaneous tissue with curved scissors, and is spread upon the surface of the wound. If too large to lie flat, it may be shaped by trimming the edges with the scissors. Some surgeons use sutures, but it is generally considered better to avoid them, as they promote suppuration, and to tuck the edges of the flap beneath the margin of the wound, which has been undermined to receive them. A sheet of sterilized goldbeater's skin or thin rubber tissue is placed over the flap, iodoform is dusted upon it, and it is held in place by a compress of gauze or cotton and a bandage, which are not removed for three or four days. Even then it may not be necessary to disturb the transparent tissue through which the flap can be inspected. It is well to leave the lids united for some months, as this opposes the contraction of the new lid. This contraction is the drawback of the operation. The immediate result, in successful cases, is perfect, and in some that have been reported it has remained satisfactory for months or a year or two, while in others the flap has contracted to a line or has even disappeared altogether by absorption. Fryer reports a case in which there had been little or no retraction in eighteen months, but six years after the operation the contraction had reproduced an ectropion. (Trans. Am. Oph. Soc., 1885, page 146; 1890, page 626.) The investigations of Garre ("Beiträge zur klin. Chir.," Bd. IV., S. 625) seemed to show that the useful part of the flap is the deep layer of epidermis, while the superficial layers are likely to slough and the dermic layer is absorbed. As would be expected from this view, a Thiersch graft shrinks less than one of skin.

Fig. 282. Snydacker Blepharoplasty. Operation completed; bridge to remain in place until flap unites.

The Thiersch flap includes only the epidermis and a superficial layer of the derm. It is usually taken from the inner surface of the arm. This surface and the wound are prepared as in the case of the Le Fort operation. The skin is put on the stretch by grasping the other side of the arm while the flap is shaved off with a sharp razor and applied directly to the wound and a little beyond its margins. Sutures are not usually required, and the same dressings are used as in the Le Fort operation.

III. DISEASES OF THE CONJUNCTIVA.

Hyperæmia.—In simple hyperæmia of the conjunctiva the blood-vessels are overfilled and there are more or less watering of the eye and a sensation of burning or smarting, but no mucous or purulent discharge. Its causes are the irritation of foreign bodies, dust, smoke or glaring light, strain, overuse of the eyes, alcoholism, etc., or it may be the beginning of a conjunctivitis or iritis. As the vessels of the conjunctiva are larger and more numerous over the posterior part of the ball, a greater degree of congestion near the corneal margin should excite suspicion of an affection of the cornea or iris. Chronic hyperæmia is frequently the result of defects in refraction, or it may depend upon lachrymal obstruction or catarrh of the nasal passages.

Catarrhal Conjunctivitis.—In simple catarrhal conjunctivitis there is an aggravation of the symptoms of hyperæmia—an increase in the flow of tears and a secretion of mucus mingled, in the worse cases, with a few pus corpuscles. It is probably not contagious, but, as it is not always possible to distinguish it from other forms, it is safer to consider so any case in which there is a conjunctival discharge. The prolonged use of atropia sometimes causes conjunctivitis, usually accompanied by erythematous inflammation of the skin of the lids.

Acute Contagious Conjunctivitis.—This is an infective disease caused by a bacillus which has been described by Weeks. It often occurs as an epidemic in connection with influenza and is popularly known as "pink eye"—a term borrowed from the horse-doctors. There are intense congestion of the conjunctiva of the lids and ball and a free yellowish muco-purulent discharge which dries on the lashes in crusts and may make it impossible to open the eyes in the morning until they have been washed. In bad cases the lids become œdematous. There is frequently accompanying catarrh of the nasal passages.

A subacute form of conjunctivitis is due to the diplobacillus described by Morax and Axenfeld. There is marked congestion with more or less smarting and burning, particularly in the evening or after reading, but not much discharge. It has a tendency to chronicity, and may last for weeks or months.

Purulent Conjunctivitis.—Purulent conjunctivitis may be caused by other pyogenic organisms, but in a large proportion of cases is produced by the gonococcus (gonorrhœal ophthalmia). It commences with symptoms of acute conjunctivitis and with a serous discharge which soon becomes purulent and has a creamy consistency. The lids are inflamed and œdematous, and the conjunctiva is swollen (chemosed) and may be so raised around the margin of the cornea as to give the latter the appearance of being set at the bottom of a cup. The great danger is involvement of the cornea, which is bathed in a virulent discharge while its circulation is impeded by the chemosis. A crescentic ulcer forms at its margin, or the centre sloughs and a perforation occurs, with prolapse of the iris and ultimately a leucoma or staphyloma. Numerous investigations have shown that about one-third of the inmates of blind asylums owe their misfortune to purulent ophthalmia. The most virulent, as well as the most frequent, form of purulent conjunctivitis is that caused by the gonococci, which may be detected in the discharge by the microscope. To this form belong a large proportion of the cases of the ophthalmia of the newborn (ophthalmia neonatorum); though some of the milder cases may be due to contact during labor with leucorrhœal discharge in the mother's vagina, or possibly to want of cleanliness in the care of the child after birth.

Metastatic Gonorrhœal Conjunctivitis.—This form of conjunctivitis is comparatively rare. It is a rather mild, but persistent, conjunctivitis, occurring in subjects of gonorrhœa or gleet, without exogenous infection, and is usually accompanied by articular inflammation.

Phlyctenular Conjunctivitis (vesicular or herpetic conjunctivitis, scrofulous or strumous ophthalmia).—This form of conjunctivitis is characterized by the appearance, usually near the corneal border, of one or more vesicles, which break down and leave more or less persistent ulcers on vascular and swollen patches of the conjunctiva. Though there is inflammation of the whole conjunctiva, it is much more intense about these ulcers. There is usually a good deal of pain and photophobia, particularly if the cornea is involved, with considerable muco-purulent discharge which collects in crusts upon the lashes. The disease occurs most frequently in badly nourished children of the poor, particularly those with a tuberculous tendency, and is nearly always, in adults as well, a sign of lowered vitality.

Granular Conjunctivitis or "Granular Lids."—Granular conjunctivitis is often considered synonymous with trachoma, but it is a condition which is also found in chronic catarrhal or purulent ophthalmia, when it consists of hypertrophy of the normal papillæ of the mucous membrane. These "granulations" somewhat resemble the granulations of a healing wound, but are flattened by pressure upon the ball and their sides are more or less compressed by the crowding of their neighbors. They are of a bright or pale red color, of rather soft consistence, and sometimes bleed when touched. Compared with the true trachoma granules, they are more superficial and do not end in cicatricial contraction as do the latter.

Follicular Conjunctivitis.—Follicular conjunctivitis is characterized by the appearance of enlarged follicles in the retrotarsal folds, particularly the lower. They are of a grayish-yellow color and bear a remarkable resemblance to frog spawn, and hence are sometimes called "frog-spawn granulations." This form of conjunctivitis occurs usually in persons living much indoors in vitiated atmosphere, and is met with most frequently in charity schools and children's asylums.

Trachoma.—Although trachoma is considered an infectious and contagious disease, its microbe has not yet been determined. The conjunctival surface of the lids and the retrotarsal folds are the seat of "granulations" consisting of the enlarged papillæ found in other forms of chronic conjunctivitis, and the characteristic small, firm, rounded, grayish "sago-grain" granules deeply embedded in the conjunctiva. These are new formations, and their subsequent transformation into connective tissue and the inflammatory changes in the deep layers of the conjunctiva and the underlying cartilage result in cicatricial contraction, which distorts the lids and is the causative factor in nearly all the more serious cases of entropion. When the papillary granulations are exuberant they may conceal the true granules, but, in typical cases, particularly in the later stages, the latter are abundantly in evidence. There is more or less abundant mucopurulent discharge and, when the cornea is involved, there is also a good deal of pain with photophobia. This involvement of the cornea is a serious menace to sight. As a manifestation of the disease or as a result of the friction of the roughened surface of the lid, probably both, the cornea, especially in its upper portions, becomes vascular. This vascularity may become intense and be accompanied by erosions, infiltrations, and proliferations of epithelium until a condition results that has been called pannus or cloth-like, and may extend over the greater part or the whole of the cornea. In some cases there are ulcerations which occasionally perforate, causing prolapse of the iris and perhaps staphyloma, as the cornea may lose its elasticity and resistance and, yielding to intra-ocular pressure, become conical. In any case its curve is likely to be more or less altered and its refraction disturbed by little faceted depressions which give rise to irregular astigmatism. In the final stage of a bad case that is said to be "cured" the conjunctival surface of the lid is more or less cicatricial. The patient is fortunate if he escapes without trichiasis or entropion. Both eyes are almost invariably involved.

Trachoma is essentially a disease of the lower orders of society, occurring chiefly among the poor living in crowded habitations with bad hygienic surroundings. Inveterate epidemics have often occurred in soldiers' barracks and in asylums and other public institutions. Different races vary much in their susceptibility to the disease. The largest proportion of cases is found among the Irish, but many are furnished by Russian and Polish Jews, Hungarians, and Italians. According to Burnett the negro is practically exempt. Some authors (Burnett) maintain that trachoma is not a simple local disease, but rather the local manifestation of a dyscrasia, and that the discharge is contagious only because it sets up a purulent ophthalmia which develops a latent tendency to trachoma. At all events there seems to be no doubt of its power of transmission.

Vernal Conjunctivitis; Circumcorneal Hypertrophy of the Conjunctiva; Spring Catarrh.—This form of conjunctivitis is most frequent in children and young people, and derives its name from the fact that it is a disease of warm weather, usually beginning in the spring, and is likely to last until the end of summer. It often occurs year after year, for three or four years, or longer, but the ultimate prognosis is favorable. In typical cases the inner surface of the upper lid is covered with broad and flat papillæ and presents a bluish-white appearance as if covered with a layer of skimmed milk, and, which is the distinguishing mark, there is a thickening of the conjunctiva near the corneal margin, consisting of proliferated epithelium and hypertrophied conjunctival and subconjunctival tissue (pericorneal hypertrophy). This hypertrophy forms grayish gelatinous-looking patches, usually at the inner and outer margins of the cornea, or a band extending nearly or quite around the whole circumference. The disease is nearly always bilateral.

Parinaud's Conjunctivitis (Lymphoma of Conjunctiva).—This is a rare disease characterized by polypoid granulations of the palpebral conjunctiva, swelling of the lids, and enlargement of the pre-auricular and submaxillary lymph nodes. It usually occurs in one eye only. In some cases there are constitutional symptoms, such as rigors and depression. Its etiology is not known.

Croupous Conjunctivitis.—Sometimes in cases of purulent or severe catarrhal conjunctivitis the plastic exudation forms a rather consistent grayish membrane which covers the palpebral and retrotarsal conjunctiva, to which it adheres with considerable firmness. It can be removed with some effort, with the forceps, or by wiping with absorbent cotton, a raw and sometimes bleeding surface being left. It is often difficult to differentiate between this and diphtheritic conjunctivitis, and it has sometimes been called pseudo-diphtheritic ophthalmia. The membrane is more superficial, and its attachment to the conjunctiva is less firm, and there is not the excessive swelling and rigidity of the lids. The Klebs-Loeffler bacillus is absent.

Diphtheritic Conjunctivitis.—In this form of conjunctivitis the lids are swollen, tense, and rigid, and it may be impossible to evert them. The false membrane is infiltrated and seems a part of the conjunctiva. It frequently occurs in areas or patches which sometimes slough out, but in favorable cases seem to be absorbed, but they are not simply cast off as in croupous ophthalmia. The discharge is at first watery or serous, but later becomes purulent. The infiltrations of the conjunctiva shut off the blood supply of the cornea, and cause it to ulcerate or in some cases to slough out entirely. The constitutional symptoms are the same as those of diphtheria elsewhere, which diphtheritic conjunctivitis often accompanies. The diphtheria bacillus should be sought for.

Exanthematous Conjunctivitis.—A conjunctivitis accompanies influenza, scarlet fever, smallpox, and particularly measles, and is a most troublesome complication of hay fever. The eruption of smallpox is sometimes found upon the bulbar conjunctiva, but otherwise the conjunctivitis occurring in connection with these diseases may be hyperæmic, catarrhal, or purulent, and does not differ essentially from these forms as they are observed when occurring independently.

Ophthalmia Nodosa.—This is a rare affection, due to the presence, in the conjunctiva, of the hairs of certain kinds of caterpillars. It is thought to be due not merely to mechanical irritation, but rather to a chemical irritant or poison in the hairs. It is characterized by the appearance of grayish-yellow nodules and a high degree of pain and congestion. The cornea, ciliary body, iris, and choroid may be involved in the inflammation. The hair has been discovered by the microscope in the nodules removed from the eye.

Argyrosis.—Argyrosis is a staining of the conjunctiva of a purplish hue due to the continued use of silver. The nitrate should never be entrusted to patients who are likely to continue its use indefinitely, and when used by the physician frequently, for a long time or in strong solutions, it should be carefully washed out or neutralized by salt solution. Protargol and argyrol have the same effect as the nitrate.

Syphilitic Conjunctivitis.—Cases of chancre of the conjunctiva, occurring either primarily or as an extension from the lids, have been observed. Mucous patches have been reported, and tertiary ulcers resulting from the breaking down of gummata sometimes extend to the conjunctiva from the skin of the lid margin. The line where skin passes over to mucous membrane is considered by some authorities as a place of election for these ulcers.

Tuberculosis of the Conjunctiva.—This is of rare occurrence, but it has been observed in the form of small ulcerations, yellowish nodules, growths resembling trachoma granules, and distinct polypoid growths, or in the form of lupus. It usually attacks only one eye. Lupus generally commences in the skin and extends to the conjunctiva, but is sometimes primary in the latter. It appears first in the form of yellowish nodules which break down and form an ulcer with ragged edges. The neighboring lymph nodes are indurated.

Tuberculosis of the conjunctiva is not always easy to differentiate from trachoma, syphilis, or epithelioma. In trachoma the lymph nodes are not indurated and the disease yields more or less to local treatment—by copper and silver; epithelioma is a disease of more advanced life, while tuberculosis usually occurs in young subjects; in the case of syphilis the diagnosis will depend mainly on the history and the therapeutic test. Only the discovery of the tubercle bacillus or inoculation experiments can confirm the diagnosis. In some suspected cases, however, with well-marked clinical symptoms, the bacillus has not been found.

Tuberculous infection may enter through a traumatic lesion of the epithelium or a phlyctenular ulcer, or may be endogenous.

Pemphigus of the Conjunctiva.—Pemphigus occurs rarely in this part of the body. It is characterized by the appearance of bullæ which frequently recur and leave the conjunctiva in a cicatricial and shrunken condition. The retrotarsal fold is obliterated, and the movements of the eye are impeded. The nutrition of the cornea may be impaired so that it becomes opaque. In some cases the lids adhere to the balls in consequence of the loss of epithelium of the opposing surfaces. A condition similar to the final steps of pemphigus is said to occur sometimes independently, and has been called "essential shrinking" or "essential atrophy of the conjunctiva."

Xerosis (XEROPHTHALMIA).—Etymologically, xerosis means dryness of the conjunctiva, and in that sense the term has been applied to a condition resulting from various forms of destructive inflammation, such as pemphigus, diphtheria, trachoma, etc., or from exposure of the conjunctiva resulting from ectropion or lagophthalmos, but it also occurs as a primary disease. The conjunctiva is anæsthetic, dry, parchment-like, and shrunken, and glistening patches form on the portion exposed between the lids. The cornea may become opaque and sometimes ulcerates. When xerosis occurs as the result of disturbance of nutrition in a general disease, there is a frothy secretion from the conjunctiva, and in many cases hemeralopia (*nyctanopsia—night blindness*) is present. Some authors have described a special microbe similar to the diphtheria bacillus. The central nervous system has been thought to be involved.

Pinguecula.—This is a little rounded elevation of the conjunctiva near the corneal margin, of a yellowish color suggestive of fat, of which it was formerly thought to consist. It is chiefly an accumulation of degenerated subconjunctival connective tissue, and is thought by some authors (Fuchs) to be the commencement of pterygium; but this view is not generally adopted, as pinguecula is usually, if not always, stationary and harmless.

Pterygium.—Pterygium is a thickening of the conjunctival and subconjunctival tissue, forming a triangular mass with its apex in the corneal margin and its base usually at the inner angle of the eye, though it is occasionally on the temporal side. Its tendency is to encroach more and more upon the cornea, but it rarely covers the pupil. Sight is endangered in proportion as the pterygium involves the pupillary area of the cornea, but may be more or less disturbed by the astigmatism caused by a change in the corneal curvature. The contraction of a dense pterygium sometimes restricts the movement of the eyeball to the opposite side.

Ecchymosis.—Ecchymosis is the result of the rupture of conjunctival or subconjunctival vessels. It may be confined to a small patch or be distributed under the whole bulbar conjunctiva, elevating it up to the corneal margin (chemosis). It is frequently the result of violent straining, as in coughing or vomiting, is not uncommon in children with whooping-cough, and is sometimes met with in violent inflammation of the conjunctiva. It also occurs spontaneously in old people, when it is an indication of weakened blood-vessels, and should suggest inquiry into the condition of the general health and particularly of the kidneys. When occurring as the result of a blow upon a distant part of the head, it may be a symptom of fracture of the base of the skull.

Œdema.—Œdema, an extravasation of serum beneath the conjunctiva, occurs in severe inflammations or from simple transudation, as in Bright's disease. It is sometimes due to escape of aqueous humor from a fistulous opening in the corneal margin following an operation.

Chemosis.—The bulbar conjunctiva, being but loosely attached to the ball, is frequently raised to the margin of the cornea, where it is adherent, by extravasations of blood or serum, so that the cornea seems placed at the bottom of a pit.

Emphysema.—Emphysema is caused by a communication between the subconjunctival space and the air spaces of the neighboring accessory cavities—usually by traumatism, but occasionally by disease of the bone. When such a communication exists air is forced beneath the conjunctiva by blowing the nose. Emphysema is recognized by the crepitation produced on pressure by the fingers, and by the puffing up of the conjunctiva when the nose is blown.

Epithelioma and Sarcoma.—These new-growths may extend from the skin of the lid to the conjunctiva or they may originate in the latter, usually at the limbus. In the latter position epithelioma appears as a flat tumor with a broad base and a tendency to ulcerate. Sarcoma is often pigmented (melanosarcoma) and tends to grow in depth rather than in width. Both are affections of advanced age.

Dermoid Tumor.—This variety of tumor is also found at the limbus, involving both conjunctiva and cornea. It is a firm, smooth, whitish growth with the composition of external skin, and sometimes contains fine hairs.

Lipoma.—Subconjunctival lipoma is rare, but is occasionally met with as a soft yellowish flattened tumor on the upper part of the eyeball. It is congenital, but sometimes grows.

Cysts.—Cysts of the conjunctiva appear in small, clear, pearl-like vesicles originating in dilated lymph-vessels. The cysticercus has been met with.

Papillomata.—Papillomata are small nodulated tumors with a raspberry-like surface. They have a tendency to recurrence.

Granulomata.—Granulomata spring from a space where there is loss of substance, sometimes from ulceration, but usually from injury or operation. They are frequent after tenotomy.

Fibroma and Osteoma.—Cases of fibroma and osteoma have been observed, but they are rare.

Lithiasis.—This condition is characterized by the presence of small yellowish spots beneath the palpebral conjunctiva. The inspissated secretion of Meibomian glands undergoes calcification and becomes a source of irritation.

Injuries.—Injuries of the conjunctiva are often inflicted by alkaline or acid caustics, the former usually in the form of lime, and sometimes of ammonia. Sulphuric acid, applied either with criminal intent or by accident, as in the case of workmen in chemicals, is the acid which most frequently causes injury. The danger depends upon the extent and depth of the injury and upon the fact whether or no the cornea is involved. If the epithelium on the opposing surfaces of lids and ball is destroyed, symblepharon will result. Foreign bodies, such as grains of dust, particles of coal, cinders, etc., frequently lodge in the conjunctiva. They usually lodge at first just within the margin of the upper lid, but are soon pushed up by the movements of the ball and by rubbing the lid, and are found about the middle of the latter. Immediately after their entrance they can often be removed by drawing the upper lid down over the lower and pressing it while the eye is opened, when they are wiped off. Grains of powder embedded in the conjunctiva have generally been sterilized by the heat of the explosion and cause little or no reaction.

Treatment of Diseases of the Conjunctiva.—Soothing and antiseptic applications, and sometimes mild astringents, are required in simple hyperæmia. Borax and boric acid are useful, either separate or combined. A wash much used at the Wills' Eye and Pennsylvania Hospitals, and familiarly known as "B and B," consists of borax gr. v., boric acid gr. xv., camphor-water fl. ʒ ii. and distilled water fl. ℥ i. This is instilled freely three or four times a day by means of a pipette. In chronic cases errors of refraction, which may be the chief or only cause, should be looked for and carefully corrected, and attention should be given to the nasal passages and tear ducts. Alum (gr. ss.) may be substituted for the borax. Douching the closed eyes with hot or cold water often gives much relief. The eyes should not be used for near work, particularly by artificial light, and, if there is much photophobia, smoked glasses are useful. Bandaging is injurious.

Catarrhal conjunctivitis, in its early stages, requires much the same treatment as hyperæmia. If the discharge is considerable, the application of yellow oxide ointment (gr. ¼ to ʒ i. of cerate or cosmoline) to the margins of the lids at night prevents their adhering and relieves the accompanying blepharitis. Frequent douching with 1-to-5,000 bichloride solution is useful. If the palpebral conjunctiva is much congested, glyceride of tannin or silver nitrate (gr. iv. to fl. ℥ i.) may be applied by means of absorbent cotton, twisted on the end of a probe or match-stick, to the everted lid, at intervals of one or two days. In more persistent cases the alum crystal is a good application. These applications should be washed off with wet absorbent cotton before the lid is allowed to close upon the cornea. In the acute contagious form, in addition to the above treatment, iced cloths may be applied constantly or for half an hour or an hour at a time, three or four times a day. Squares of lint or gauze, folded only once, are kept on a block of ice and applied continuously, being changed every few seconds, as otherwise they soon become warm and may do more harm than good.

In the diplococcus form of conjunctivitis, zinc sulphate (gr. ½ to gr. i.) or zinc chloride (gr. ¼ to gr. ss.) is the most useful application. Cocaine (gr. i.) may be added to mitigate the smarting.

Purulent conjunctivitis, particularly the gonorrhœal, is a dangerous disease, and requires active and careful treatment. In the earlier stages, when the lids are hard and stiff and there is little or no purulent discharge, the chief reliance is upon iced compresses, applied as in the acute contagious form, but continuously day and night—the conjunctiva being meantime flushed every hour or two with a mild antiseptic solution, such as boric acid. Leeches to the temple are sometimes useful. When the conjunctiva becomes succulent and swollen and the discharge purulent, the flushing should be done with 1-to-5,000 solution of bichloride of mercury or potassium permanganate, the iced compresses being continued. The lids should now be everted and a solution of silver nitrate (gr. x. to ℥i.) brushed over them once or twice a day. Toluidin blue (1 : 1,000) makes a good application. Dr. Standish and others claim good results from the instillation of argyrol (twenty to fifty per cent) every hour. I have found this useful, but do not think it can supplant the nitrate. Both may be used. Argyrol is an excellent antiseptic, and its application, even in strong solution, is painless. If the cornea is hazy and threatens to ulcerate, atropia should be used, gr. iv. to fl. ℥i., three or four times a day. Commencing ulceration of the cornea is best treated by the actual cautery. If a galvanic cautery is not at hand, the end of a probe or a stout strabismus-hook, brought to a red heat in an alcohol lamp, answers the purpose as well. The cauterizing is not painful if the eye is thoroughly cocainized. I have been for many years in the habit of using a small cautery iron with a bulb and a probe-point. (Fig. 294.) If the lids are very tense a free canthotomy is useful, and chemosis may be relieved by slitting the conjunctiva freely with sharp-pointed scissors. Anodynes and tonics are often required.

When one eye only is affected, the other should be protected carefully from contagion. This may be done by covering the closed eye with a compress of absorbent cotton wet with 1-to-5,000 solution of bichloride, and placing over this a square of gauze, the whole being held in place by strips of rubber adhesive plaster. The edges of the gauze on the nasal side should be held close to the skin by collodion. Or, to avoid the depressing effects of continued darkness, the Buller shield may be used. This consists of a watch glass fitted in rubber plaster, applied over the eye and retained by additional strips of plaster. Collodion is applied to the nasal edges of the plaster. If there is any sign of commencing conjunctivitis in the sound eye, a ten-grain solution of nitrate of silver, or a fifty-per-cent solution of argyrol, should be applied at once. Great care should be taken to disinfect the hands of the surgeon and nurse, and all cotton or gauze that has been in contact with the discharge should be destroyed, as the contagion is most virulent.

Ophthalmia neonatorum is treated on the same general principles as purulent ophthalmia in the adult. As to prophylaxis, it may be stated that the prevalence of ophthalmia neonatorum, particularly in maternity hospitals, has been greatly diminished by the treatment introduced by Credé, and known by his name. In the Leipsic Lying-in Asylum, the percentage sank from 10.8 per cent to .02 per cent. He advises the instillation of a two-per-cent solution of silver nitrate in the eyes of every infant so soon as the head is born. This is strenuous treatment, and is sometimes followed by excessive reaction. It may perhaps be limited, in private practice at least, to cases in which it is known that the mother has a vaginal discharge; while in others a careful cleansing with a mild antiseptic wash, such as boric acid or a 1-to-5,000 solution of bichloride of mercury, or of potassium permanganate, may be safely substituted, or a fifty-per-cent solution of argyrol would perhaps be equally efficient. In any case the conjunctival sac should be carefully cleansed as soon as the child is born. Usually the infant's lids are easily everted, and it is better to avoid the bleeding that results from canthotomy or slitting the conjunctiva. Hot stupes may be substituted for cold applications earlier than in the case of the adult. A solution of argent. nit. (gr. ii. in aq. destillat. fl. ℥i.) may be instilled three times a day by the nurse, while the stronger solution (gr. x.) is applied to the everted lids by the surgeon once or twice daily. The argyrol treatment would also seem to be applicable, though I have no personal experience in its use.

Phlyctenular ophthalmia, which usually indicates a depression of the general health and is often associated with tuberculosis, requires tonic treatment together with plenty of fresh air and nourishing food. Quinine and cod-liver oil are useful, and syrup of the iodide of iron is a favorite prescription. In the early stages atropia (gr. ii. to ℥i.), to which boric acid is often added, is the most useful application. If there is much conjunctival congestion, gr. ss. of alum may be combined with the atropia and boric acid. Later, when the pupil is dilated and the eye is less irritable, calomel is dusted from a camel's-hair brush upon the ulcer, or the yellow-oxide-of-mercury ointment is applied to the ball. If there is a persistent ulcer of the cornea which tends to perforation, it should be lightly touched with the actual cautery. The benzoated oxide-of-zinc ointment is a good application for the excoriated and eczematous skin of the lids. It is well to apply the yellow-oxide ointment to the lid margins at night.

In follicular conjunctivitis fresh air is an important element in treatment, and the usual antiseptics and astringents are applied locally. The follicles may be punctured or expressed.

Vernal conjunctivitis yields only to time and cooler weather, but the patient's discomfort may be much relieved by proper treatment. A sojourn in the country, particularly in the mountains, or in a more northern climate, should be advised, if practicable. Mild astringents and occasional applications of weak solutions of silver nitrate are useful, and the burning and itching and congestion may be much relieved by a wash composed of cocaine gr. i., salt gr. v., and solution of adrenalin chl. (1 to 3,000) fl. ℥ i. Acetic acid (gtt. xx. of the dilute acid to fl. ℥ i.) has been highly recommended. Yellow-oxide ointment may be applied to the eyeball, and some surgeons destroy the granulations by electrolysis. The application of iced cloths or a cold spray on the closed lids is very soothing.

In Parinaud's conjunctivitis the usual treatment of other chronic forms is supplemented by excision of the growths.

The object of treatment in trachoma is to allay the inflammation, neutralize the infection, and promote the absorption of the granulations. The most valuable application to meet these indications is the nitrate of silver. In addition to frequent cleansing with boric acid or other antiseptic wash, the nitrate solution (gr. x. to gr. xx. to fl. ℥ i.) should be applied daily or every other day to the everted lids. In very chronic cases, with much thickening of the conjunctiva and abundant granulations, the mitigated stick (1 argent. nit. to 2 of potass. nit.) is preferred by some surgeons to strong solutions. The nitrate should be left upon the lid for a few seconds, and then washed off or neutralized with salt water before the lid is allowed to come in contact with the cornea. These applications should never be entrusted to patients, as their long-continued or careless use will stain the conjunctiva (*argyrosis*). When the patient cannot be seen frequently by the surgeon, one of the best substitutes for nitrate of silver is chloride of zinc, a solution of which (gr. ss. to gr. i. in fl. ℥ i.) is to be instilled daily or several times a day. Treatment may be varied by the occasional use of glyceride of tannin, boroglyceride, 1 to 5,000 bichloride, or the alum or sulphate-of-copper crystal. In the more chronic cases, when the acute inflammation has subsided and the cornea is not ulcerated, some surgeons prefer the copper crystal to nitrate of silver. It is a severe application, but the pain that is caused may be mitigated by cocain. Free scarifying of the granulations and encouraging the

FIG. 283.—Knapp's Roller Forceps.

bleeding from the incisions often prove useful. "Grattage" is breaking up the granulations with a stiff brush; or their contents may be pressed out by means of the Knapp roller forceps. (Fig. 283.) The lid is everted, and one roller is pushed into the cul-de-sac, while the other rests on the palpebral conjunctiva. The arms of the forceps are firmly closed and they are drawn forward. This operation requires general anæsthesia. Pannus or ulceration of the cornea is usually relieved by treatment of the lids, but is benefited by atropia and the yellow oxide-of-mercury ointment (gr. ss.–ʒ i.). In very chronic cases, when the pannus is dense and consists in great part of non-vascularized connective tissue, marked improvement sometimes results from exciting an acute muco-purulent conjunctivitis by inoculating the pus from a mild case of purulent ophthalmia (neonatorum), or by the use of jequirity. A three- to five-per-cent infusion made by steeping the ground seeds of jequirity in cold water for twenty-four hours, is applied two or three times a day to the everted lids. The infusion should be prepared fresh every day. Sufficient inflammation is usually produced on the second or third day, when the lids become œdematous and the palpebral conjunctiva is covered with a croupous membrane. The inoculation with pus is no longer employed, as it involves danger (by contagion), not only to the patient, but also to others about him, and even jequirity ophthalmia is not altogether free from danger, though the discharge is not contagious, the inflammation being caused by a chemical irritant and not by a microbe. It may require careful treatment by iced cloths, etc. The active principle, abrin, has been used.

A good application for cleansing the eye and removing the membranous deposit in croupous conjunctivitis is a solution of borax (gr. x. to fl. ℥i.) frequently and freely applied. When the membrane has been detached from the palpebral conjunctiva, a solution of bichloride of mercury or of potassium permanganate, 1 to 1,000, may be painted over the everted lids once or twice a day, iced cloths being in the mean time continuously applied. Later, when there is a muco-purulent discharge, nitrate of silver is the best application.

In true diphtheritic conjunctivitis much the same local treatment is applicable except that hot stupes are better than cold applications. The main reliance, however, is to be placed upon the administration of antitoxin as in other forms of diphtheria.

Exanthematous conjunctivitis is treated in the same way as the ordinary catarrhal form.

In conjunctivitis nodosa the nodules containing the offending hairs must be extirpated by taking them up in conjunctival forceps and snipping them off with curved scissors.

Syphilitic diseases of the conjunctiva require constitutional treatment with mercury and iodides.

Not much can be accomplished by treatment in pemphigus. The administration of arsenical preparations is recommended. Fluid albolin or glycerin and water give much relief to the dryness. Much the same may be said of xerosis. Pinguecula and pterygium may be removed by operation. Ecchymosis will disappear spontaneously, but absorption of the blood may be hastened by hot applications and a pressure bandage. In traumatic cases iced cloths should be used at first to check any continued extravasation. Chemosis is relieved by slitting the conjunctiva with sharp-pointed scissors. In lithiasis, the calcareous deposits can be removed by the point of a Graefe knife. Emphysema will usually disappear in a short time if the patient is cautioned against blowing his nose or straining in any way. A compress bandage may be needed.

Foreign bodies in the conjunctival sac can generally be easily removed, after cocainization, by everting the lid and wiping them off with a small wad of absorbent cotton or with a fold of a handkerchief. If embedded in the palpebral conjunctiva they can be lifted out with a spud, or, if in the bulbar conjunctiva, they may be taken up in the points of a small forceps and cut out with fine scissors. They usually lodge first just within the lid margin, and can then often be removed by drawing the upper lid down over the lower and pressing it as the eye is opened.

In burns by acids or alkalis, it is of the first importance to be sure that the offending substance has been completely removed by douching and wiping with wet absorbent cotton, but, at the same time, it may be chemically neutralized. In burns by acids the eye should be douched with a solution of borax or sodium bicarbonate (gr. x. to fl. ℥ i.). Lime may be neutralized by diluted vinegar (fl. ʒ i. to fl. ℥ i.) or by milk or a solution of sugar. Olive oil is useful in either case. Pain is best relieved by cocaine (four per cent). The subsequent treatment includes the application of iced cloths, frequent douching with boric-acid solution, and, if the cornea is involved or the conjunctival burn is deep, the instillation of atropia dissolved in olive or castor oil or fluid albolin. If the opposing surfaces are deprived of epithelium, symblepharon cannot be avoided, and may be left to future operative treatment, but may perhaps be lessened by frequent separation of the parts. Granulomata are snipped off with scissors and theirs bases touched with the mitigated stick of nitrate of silver. Cocaine prevents all pain.

In the various forms of conjunctival growths it is a question of operative interference. (See pages 570 and 584.)

IV. DISEASES OF THE SCLEROTIC AND EPISCLERAL TISSUE.

Episcleritis.—Episcleritis is an inflammation of the superficial layers of the sclera and the overlying tissue beneath Tenon's capsule. It frequently occurs as a localized patch several millimetres from the corneal margin on the temporal side, but may extend over the whole of the visible sclerotic. The blood-vessels are small and deeply situated, and their congestion gives a pinkish hue to the sclerotic over which the conjunctival vessels move freely. The conjunctiva may be only slightly or not at all congested. In the localized form the patch is sometimes decidedly raised and tender to the touch. There are generally considerable pain and more or less irritability and photophobia. Episcleritis is sometimes associated with syphilis, but is most frequently due to rheumatism or gout. In some cases it shows a tendency to recur at intervals of a few weeks or months, each attack lasting only a few days (*Scleritis fugax*). A deeper inflammation, chiefly or entirely in the sclerotic itself, occurs in connection with cyclitis, chronic choroiditis, and panophthalmitis. The sclerotic becomes thin and has a bluish tinge from the color of the choroid seen through it. Sometimes it yields to intra-ocular pressure, and staphylomata are formed. Neoplasms originating in the sclerotic are very rare, but the sclerotic is often involved in conjunctival or intra-ocular growths.

Treatment.—Locally, hot applications give most relief. Either hot stupes or dry heat may be used. Atropia is useful. Internally, the remedies for rheumatism, gout, or syphilis are needed. In the greatest number of cases large doses of salicylates will do most good.

Pigment Patches.—These are not uncommon in the negro.

Wounds.—Wounds in the sclerotic should be closed with fine sutures, and the conjunctiva should be stitched over them, after careful disinfection.

V. DISEASES OF THE LACHRYMAL APPARATUS.

Catarrh of the Lachrymal Sac and Duct; Dacryocystitis.—Catarrh of the lachrymal sac and duct is of frequent occurrence, and usually originates by extension from the nose. In its earlier stages and milder form it may cause only a slight epiphora, particularly under exposure to the wind or after use of the eyes, and a lachrymal conjunctivitis, but too often the duct becomes obstructed by swelling or cicatricial contraction of the lining membrane, and the sac is distended with tears and mucus. This accumulated fluid contains bacteria from the conjunctiva and the nose, and these set up a muco-purulent inflammation of the mucous membrane and submucous connective tissue, causing a dacryocystitis and ultimately an abscess of the sac.

In dacryocystitis there is a swelling at the inner angle of the orbit, beneath the tendon of the motor oculi, pressure upon which causes a regurgitation of the tears and pus by way of the punctum. The skin is red and sensitive, and the distention of the sac causes intense pain, while the tears and conjunctival discharges overflow the lids and irritate the skin. After a time temporary relief is obtained by spontaneous or operative perforation of the skin and the formation of a fistula. This may close, however, when the pressure is relieved, and the abscess will then form again; or, in case of complete and continued obstruction of the duct, the abscess may be permanent. The stricture usually occurs at the narrowest part of the passage, at the bottom of the sac where it opens into the duct. The position next in frequency is the bottom of the nasal duct, where it ends in the inferior meatus of the nose.

Dacryocystitis occurs very rarely in nursing infants. It is noticed soon after birth, appears to be congenital, and is probably due to obstruction of the duct by turgescence of the mucous membrane or to enlarged opening of the duct. I have met with three or four cases, all of which got well in a few weeks' time without much reference to treatment.

Suppurative inflammation of the tissues in the neighborhood of the sac (prelachrymal abscess) is sometimes mistaken for dacryocystitis. Pressure on the swelling does not cause regurgitation from the punctum unless there is communication between the abscess and the sac or the canaliculus, as occasionally happens, and opening of the sac by slitting the canaliculus does not relieve the swelling.

Empyema of the frontal or ethmoidal sinus may discharge into the sac or into the neighboring tissues.

The puncta are sometimes closed, either as the result of antenatal changes or in consequence of marginal blepharitis. In the latter case the puncta have usually been everted. In ectropion or facial paralysis, epiphora results because the punctum is out of reach of the tears. The canaliculi are occasionally congenitally absent or obliterated by injury.

Diseases of the Lachrymal Gland.—These are comparatively rare. Dacryoadenitis—inflammation of the lachrymal gland—is occasionally met with, most frequently in connection with mumps. It may undergo resolution or end in suppuration and the formation of fistula. Cases of congenital fistula have been reported. Simple hypertrophy has been met with, and a curious syndrome has been described by Mikulicz (*Archives d'ophthalmologie,* Van Duyse, December, 1905), consisting of symmetrical bilateral lymphomatous enlargement of the lachrymal and salivary glands. Cases of traumatic and of spontaneous dislocation have been reported. The lachrymal gland may be the seat of various neoplasms, such as adenoma, carcinoma, sarcoma, etc. Usually a tumor of the lachrymal gland forces the eyeball forward, downward, and inward, but the direction may be more outward, or the ball may be entirely covered and hidden when the growth is very large and is no longer contained within the orbit, as in Fig. 284. (Transactions Am. Ophthalmological Society, V., III., p. 402.)

Cyst of the lachrymal gland (dacryops) is due to obstruction of a duct. Upon eversion of the upper lid it appears as a bluish fluctuating swelling which increases when the patient cries. Lachrymal calculi (dacryoliths) have been noted.

Treatment.—Cases of epiphora from partial obstruction of the duct due to swelling of the lining membrane may often be relieved by forcing antiseptic, astringent, or stimulating solutions (acid boric gr. x., alum gr. i., or zinc sulph. gr. ss.) through the passage by means of the Anel syringe. This not only acts medicinally upon the mucous membrane, but dilates the duct by hydrostatic pressure. The internal administration of potassium iodide, which charges the tears with iodine, is sometimes useful. Attention should be given to the nose and pharynx. Complete and permanent stricture requires operative treatment.

Cold applications may be made in the commencement of dacryocystitis, but if suppuration is inevitable it should be hastened by hot stupes. These, or a flax-seed poultice enclosed in a gauze bag, give much relief of pain. The contained fluid should be evacuated by a free incision, either through the skin, or, if practicable, by slitting up the canaliculus and opening the top of the sac. The latter procedure opens the way for probing when the acute inflammation has subsided.

In the early stage of acute dacryoadenitis leeching and iced cloths are useful. Later, an ointment of mercury and extract of belladonna is applied, and, when

Fig. 284.—Sarcoma of the Lachrymal Gland. (Harlan.)

suppuration threatens, a poultice or hot stupes are in order. An abscess requires early and free incision either through the skin or through the conjunctiva. Internally a mercurial purge may be followed by potassium iodide and small doses of calomel. Sodium pyrophosphate in twenty-grain doses has been highly recommended. In the chronic form mercurial and iodide ointments are applied, and iodides and mercurials are given internally; also quinine and iron. Excessive enlargement of the gland may necessitate its removal to save the eye from the effect of pressure.

Permanent fistula, hypertrophy, and new-growths can be dealt with only by operation.

VI. OPERATIONS UPON THE CONJUNCTIVA AND THE LACHRYMAL APPARATUS.

Pingueculæ may usually be let alone as harmless. If they prove disfiguring or show a tendency to develop pterygium, they are easily removed by taking them up in conjunctival forceps and cutting them off with curved scissors.

Pterygium, if it is increasing in size and creeping over the cornea, should be removed early. Arlt's method calls for the excision of a rhomboidal segment of the thickened conjunctiva. The pterygium is seized with forceps at the corneal margin, its point is shaved from the cornea with a Beer knife or keratome, and incisions are made along the upper and lower margins of the pterygium and joined by others which meet at the caruncle. (Fig. 285.) The flap so marked is dissected away and the margins of the conjunctival wound are brought together by sutures. To do this last it may be necessary to undermine the conjunctiva with scissors. Knapp, after freeing the point and dissecting up the pterygium, slits it into two flaps by an incision from point to base, and then, making incisions in the conjunctiva on the upper and lower parts of the ball, he transplants these flaps into them and sutures them in place. The space left bare by removing the pterygium is covered by suturing the edges of the wound, the conjunctiva having been undermined to enable them to be brought together (Fig. 286). The incising and undermining of the conjunctiva are done with scissors. An occlusive bandage is placed over both eyes for the first day, and after that over one only, and the sutures are removed in five or six days. Galezowski dissects up the pterygium, passes a double-needled suture through its point, doubles it back upon itself, and stitches the point under the caruncle. He then covers the bared space by bringing the conjunctiva over it.

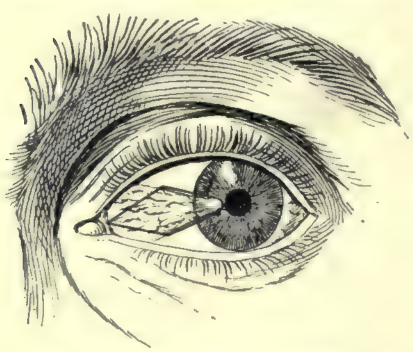


Fig. 285.—Arlt's Pterygium Operation. The dark lines show the incisions. (Harlan.)

Prince recommends tearing the point of the pterygium from the cornea instead of cutting it, and claims that it is in this way removed more thoroughly and with less loss of corneal tissue. A strabismus-hook is inserted under the pterygium at the corneal margin and drawn forcibly toward the cornea.

Szokalski cuts off the blood supply of the pterygium, and leaves it to slough off. This perhaps leaves the most satisfactory result in successful cases, but is not without danger from tenonitis (inflammation of Tenon's capsule); which, however, is reduced to a minimum by thorough asepsis and careful after-treatment with rest and iced cloths. A long thread is armed with a curved needle at each end; one needle is passed beneath the pterygium near the corneal margin and the other at its base. When the needles are drawn through and cut loose and the threads are tied, the two lateral single threads cut off the circulation at each end and the middle loop cuts it off beneath. (Fig. 287).

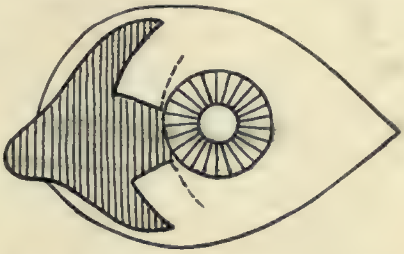


FIG. 286.—Knapp's Pterygium Operation.

It must be confessed that the result of pterygium operations is not always all that could be desired. Large ones sometimes recur, particularly if they have not been thoroughly removed and the bared space covered with healthy conjunctiva. Relapses are said, however, not usually to be so large as the original pterygium or so likely to extend. (Knapp.) In some cases a thickened and contracted cicatrix is unsightly and impedes the movements of the ball. Knapp says that pterygia that have relapsed after one or several operations and have the aspect of a keloid scar should not be meddled with. (Norris and Oliver's System.) It has been suggested to cover the bared space with a Thiersch graft.

When cysts or tumors are removed from beneath the conjunctiva, the latter structure should be preserved as intact as possible. In some cases, as in those of a cyst with distinct walls, this is easily done by raising the conjunctiva in forceps and dissecting the tumor with fine scissors. But in others a tedious dissection may be required to avoid subsequent cicatricial contractions of the conjunctiva which impede the motions of the ball.

FIG. 287.—Szokalski's Ligature Operation for Pterygium. (Stellwag.)

Dermoid tumors at the corneal margin are taken up in forceps and shaved off close to the cornea and sclerotic with a Beer or a Graefe cataract-knife. If they cannot be entirely removed without cutting too deeply, the base may be burned with the actual cautery. Sarcomatous and other malignant growths in this region may be removed in the same way, but are likely to recur and necessitate enucleation.

Stricture of the lachrymal duct is usually treated by the method known as Bowman's. Bowman advised slitting the canaliculus to admit of the use of larger probes than can ordinarily be passed through it. The canaliculus (usually the lower) is slit with the probe-pointed, narrow-bladed Weber knife. (Fig. 288.)

If the punctum is too small to admit the probe-point of the knife, it can be stretched by introducing a large pin or the canaliculus-dilator—a steel probe rather pointed at the end and gradually enlarging. While the lid is put upon the stretch by drawing the external canthus outward, the probe-point of the knife is introduced vertically into the punctum, the handle is turned to the horizontal direction, and the knife is pushed toward the nose until it impinges against the lachrymal bone. It is then in the top of the sac, and the cut is completed by raising the handle of the knife vertically, still keeping the point against the bone. One of the smaller Bowman probes, say No. 3 or 4, slightly curved to avoid tilting by the brow, and oiled, is passed along the opened canaliculus, closely hugging its floor, until arrested by the bone of the lachrymal groove, when it is turned into the sac and, with its convexity backward, is pushed, in a downward,

FIG. 288.—The Weber Probe-pointed Canaliculus Knife.

outward, and slightly backward direction, through the duct to the floor of the meatus. No attempts should be made to force the point of the probe downward until the surgeon is sure that it is engaged in the sac. This can be determined by the impression of bony resistance conveyed through the probe, and by the absence of dragging upon the lid when the probe is pushed. It is allowed to remain in place for fifteen or twenty minutes and then gently withdrawn. Every second or third day the probing is repeated, with each time a larger probe, until the largest size is reached. This probe is then used once a week, once in two weeks, and once a month until the duct is permanently patulous. This is practically the Bowman operation as now practised, except that larger probes are generally used. No. 6 is only 1.50 mm. in diameter, and is almost universally considered too small for efficient dilatation. In the sets of probes sold as Bowman's the series is usually continued to No. 12. According to Theobald (Norris and Oliver's System), the normal bony lachrymal duct averages 4.47 mm. in diameter, and Theobald has strongly urged the use of larger probes. There are sixteen probes in his set. No. 1 is .25 mm. in diameter, and they increase in size by .25 mm. until No. 16 reaches a diameter of 4 mm. The ends are not so blunt as Bowman's, but have an olive-shaped point. I have used these probes for some years, and am persuaded that the principle of wide dilatation is correct. I do not often find it necessary to use the larger sizes, but usually find Nos. 9, 10, or 12 large enough. The treatment is hastened by combining the slitting of the stricture, as recommended by Stilling, with probing. My routine practice is to pass a Weber canaliculus knife, with a large flexible shank that can be bent to the proper curve, through the duct, to enlarge the opening into the sac with a conical dilator (Fig. 289), and then to introduce a No. 9 or No. 10 Theobald probe at once. It hurts more the first time, but the sum total of pain is less than with gradual enlargement by forcible dilatation with probes of increasing size. The pain is much diminished by injecting a little cocaine into the passage with an Anel syringe. Or, if thought best, general anæsthesia may be resorted to. If at the next treatment the same probe cannot be passed without difficulty, a smaller one may be used, and larger sizes subsequently. If the wound in the canaliculus shows a tendency to close in spite of frequent reopening with the probe, this may be prevented by cutting out the posterior wall of the slit. This little operation is also often useful when eversion of the punctum prevents access of the tears to the canaliculus. No matter what the conditions may be, if any one expects to find the treatment of lachrymal stricture an agreeable process he is likely to be disappointed.

FIG. 289.—Conical Dilator.

A lachrymal fistula will nearly always close when the duct has been made pervious. If a catarrhal condition of the passage persists, antiseptic and astringent solutions may be passed through it with the Anel syringe, but this should never be done immediately after a probing, as the fluid may be forced into the surrounding connective tissue. If frequent probing is, for any reason, as in the case of small children, impracticable, a lead wire (as recommended by John Green), as large as can be conveniently introduced, may be inserted in the duct and left in place for some weeks. Its upper end is bent over and allowed to rest upon the skin, or shaved fine and lodged in the slit canaliculus. Catarrh of the sac and epiphora are generally relieved by dilatation of the duct, but if the condition still persists in spite of treatment, or if the canal cannot be re-established on account of bony occlusion, it may sometimes be necessary to extirpate or obliterate the sac. In extirpation of the sac, after washing out and disinfecting it, a free incision is made into it from the lower orbital margin upward through the tendon of the motor oculi, the margins of the wound are stretched apart with pronged retractors, and the walls of the sac are dissected out with scissors; a rather difficult undertaking on account of its close connection with the skin and the periosteum, and the free bleeding. To avoid the latter, Arlt performed the operation in two sittings, first opening the sac and packing it with gauze, and proceeding with the extirpation several days later. The lining of the duct is scraped with a sharp spoon, which is also useful in removing any remains of the sac walls. When all has been removed, the wound is closed with sutures, and iced cloths are applied, in the hope of securing immediate union.

To obliterate the sac and the duct various caustics have been used, such as nitric acid, caustic potash, and Vienna paste, but the safest are the actual cautery and the nitrate-of-silver stick. The latter may require several applications. The sac is opened in the same way as for extirpation, and, after it has been cauterized, it is packed with iodoform gauze and allowed to close by granulation. The canaliculus should also be obliterated. After extirpation or destruction of the sac, the secretion of tears seems to be greatly diminished, on the principle of suppression of the secretion of a gland by obstruction of its duct, and the epiphora is not usually very annoying. In some cases, however, it has been found necessary to extirpate the lachrymal gland, or the palpebral portion of it only, which latter is sometimes found sufficient to stop the epiphora. To remove the palpebral portion (lower or accessory gland) the external canthus is cut, the upper lid is turned up and held with a tenaculum or loop of thread, the conjunctiva is incised over the gland, and the latter is drawn down with forceps or hook and dissected out with scissors. Care should be taken not to sacrifice the conjunctiva, or cut the external or superior rectus or the levator palpebræ. To remove the orbital portion (superior gland) an incision of the skin down to the bone is made at the margin of the orbit from the junction of its middle and external thirds to a point just below the external canthus. The wound is widely separated with pronged retractors, and the incision is carried down to the gland, which is drawn down with a tenaculum and shelled out of the lachrymal fossa with blunt scissors curved on the flat, which are also used for dividing the connections. To avoid the danger of cutting the levator muscle, the orbital portion, with the palpebral lobe, is sometimes removed through the conjunctiva.

Fistula of the lachrymal gland is likely to be permanent, being prevented from healing by the constant flow of tears. Bowman operated by substituting a fistula through the conjunctiva for one through the skin. To effect this, he armed a thread with a needle at each end, entered one needle at the fistula and passed it through the conjunctiva, then introduced the other at the margin of the fistula and brought it out by the side of the first, and then, having tied the threads firmly, he left them to slough their way out on the conjunctival side.

When a new-growth has so much enlarged the gland that it is no longer contained within the orbit it is more easily removed. In the case of the sarcoma referred to at page 593, the tumor was encapsulated and, after a free incision had been made in the skin, it was easily turned out with the fingers and the flat handle of a scalpel. The eye resumed its natural position and appearance, but was blind from the effect of pressure exerted upon the optic nerve and from the stretching to which it had been subjected.

VII. DISEASES AND INJURIES OF THE CORNEA.

Superficial Keratitis.—Superficial keratitis results usually from local injury, from the irritation of roughened lids, or from an extension of inflammation from the conjunctiva. In its milder forms there is a haziness of the cornea with a pericorneal vascular zone—a pinkish zone around the corneal margin, due to congestion of the four branches of the anterior ciliary arteries in the sclera, from which vessels the cornea chiefly derives its nourishment. This zone is important, as its presence always shows that there is something more than conjunctivitis, and that either the cornea or the deeper tissues of the eye are involved. The vessels of the conjunctiva are largest and most numerous in its posterior portions, and their congestion is more evident there. There may be superficial ulcerations, destruction of corneal epithelium, or the formation of superficial vessels, particularly at the corneal margin (vascular keratitis). The most common form of vascular keratitis is that found in connection with granular conjunctivitis (see Trachoma), which may result in pannus. A common cause of superficial keratitis is exposure of the cornea from paralysis of the orbicularis (lagophthalmos) or from cicatricial contraction of the lids.

Ulcers of the Cornea.—Ulcers of the cornea that do not extend more deeply than the epithelium heal without permanent opacity. The "absorption" or "excavated ulcer" is an indolent form not accompanied by inflammatory symptoms, and involving only the superficial layers of the cornea. It is transparent, and may easily escape superficial inspection. It is essentially chronic, and may remain unchanged for weeks or months. The eye is irritable, and there may be congestion of the conjunctiva and epiphora on exposure to wind, etc., or after prolonged use. A shallow facet, which causes more or less irregular astigmatism, is likely to be permanent, and disturbs vision if centrally located. If a superficial corneal ulcer becomes infected, the ulcerative action may involve the deeper layers of the cornea. The deep sloughing ulcer, extending more rapidly in depth than in width, often results from extension of purulent inflammation from the conjunctiva, particularly in gonorrhœal ophthalmia. The *ulcus serpens* of Saemisch tends to extend centrifugally in a widening circle. It is nearly always accompanied by onyx or hypopyon (hypopyon keratitis).

Hypopyon.—Hypopyon is a collection of pus at the bottom of the anterior chamber, caused either by posterior perforation of an abscess of the cornea or by coincident inflammation of the iris or deeper tissues. The lower border of a hypopyon is crescentic, and the upper horizontal. In onyx, so called from its resemblance in form to the matrix of the finger-nail, the pus is located between the layers of the cornea, and its course from the ulcer can sometimes be traced by a fine yellowish line. Its upper border is slightly convex, as the corneal laminæ are more readily separated toward the centre than at the periphery. Its position is fixed, while if the patient lies upon his side a hypopyon will shift its position by gravity unless the deposit is very dense. These sloughing forms of keratitis are very dangerous and, unless checked by energetic treatment, rapidly destroy the eye by penetrating the anterior chamber and causing prolapse of the iris, leucoma, or staphyloma, or perhaps panophthalmitis. Sloughing keratitis often results from comparatively slight traumatic injuries inflicted by septic objects, or it may develop in an eye the conjunctival sac of which contains infecting microbes. Such a keratitis is particularly likely to occur in subjects with lowered nutrition and resistance. A special form has been described as "oyster-shucker's" keratitis, the fragments of oyster shell being supposed to act as a specific irritant. Sloughing ulcers of the cornea are sometimes met with in smallpox. They usually occur in the desquamative stage of the disease, and are generally regarded, not as true smallpox pustules formed upon the cornea, but rather as the result of abscesses caused by endogenous infection (metastatic). True pustules do, however, sometimes form on the conjunctiva, and involve the cornea by direct extension on its margin or by infection from a purulent conjunctivitis. Similar ulceration is also met with, though more rarely, in the late stages of malignant cases of scarlatina. Crescentic ulcer involves the margin of the cornea, and may form a groove extending around the greater part, or even the whole, of its circumference. It occurs most frequently in purulent ophthalmia from infection by the conjunctival secretion and from obstruction of the circulation by pressure of the chemosis and of the swollen lids. It is likely to end in perforation of the anterior chamber, with extensive prolapse of the iris, or in sloughing of the whole cornea.

Phlyctenular Keratitis.—This form of keratitis occurs in connection with phlyctenular conjunctivitis; one or more vesicles form upon the cornea and, rupturing, leave ulcers that usually involve only the superficial layers of the cornea, but sometimes perforate it and cause prolapse of the iris. In some cases a leash of new blood-vessels extends from the margin of the cornea to the ulcer (fascicular keratitis) and promotes its healing.

A penetrating ulcer causes escape of aqueous humor and hernia of the iris. Sometimes the ulcer penetrates only to the membrane of Descemet, which is more resisting and bulges through the opening, forming a little transparent tumor called a "keratocele." In most cases it finally gives way, leaving a complete perforation.

Bullous Keratitis.—This form of keratitis is rare. Large blebs form on the cornea, usually of an eye damaged by previous disease or in a glaucomatous state. They involve the epithelium and also, according to some authors, Bowman's layer. They are accompanied by considerable irritation and pain, and are liable to recur.

Neuroparalytic Keratitis.—Neuroparalytic keratitis is due to disease or injury of the fifth nerve or of its nucleus, or of the Gasserian ganglion. There has been much discussion as to whether the keratitis is caused by trophic changes, or by the irritation of foreign bodies, dust, etc., of which the patient is unconscious on account of the anæsthesia. Both are probably factors, as the healthy cornea is liable to slough if left unprotected, on account of paralysis of the orbicularis or retraction of the lids, and the anæsthetic cornea may slough, even when completely protected, by coincident paralysis of the levator; or it may become congested and hypertrophied from irritation of the trophic fibres of the fifth. (Harlan, *Am. Jour. of Med. Sciences*, 1874.)

A form of neuroparalytic keratitis occurs in connection with herpes zoster (*herpes zoster ophthalmicus*). Vesicles, similar to those found upon the skin of the eyelids and forehead or face, are formed upon the cornea, which is anæsthetic, and these vesicles rupture, leaving ulcers which usually cicatrize but occasionally perforate. There is more or less pain, sometimes very severe, and the iris is generally involved in the inflammation. The skin is swollen and red, very much like the skin in erysipelas, for which this disease is frequently, not to say usually, mistaken even by experienced practitioners. The anæsthesia of the parts supplied by the affected nerve, strictly limited to the median line of the forehead and face, should prevent this mistake.

Dendritic Keratitis.—In dendritic keratitis (malarial keratitis) the opacity and the ulcerations occur in branching lines. It is accompanied by ciliary pain, and is often complicated with iritis. In typical cases the disease commences with "a number of small grayish opaque elevations arranged in a line like a string of beads." This is followed by "a peculiar narrow serpiginous superficial ulcer with lateral offshoots." (Kipp, Trans. Am. Oph. Soc., Vol. V., p. 337). Sometimes there is iritis. Perforation is rare. Very many of the cases have occurred in subjects of malarial fever, some have been reported in tuberculous patients, and a few in apparently healthy subjects.

Filamentous Keratitis.—This is a rare form of keratitis in which threads of tissue, formed of elongated and twisted epithelial cells, hang from vesicles or from a wound, as after cataract extraction. The disease sometimes recurs, but in most cases it finally disappears without causing serious damage.

Ribbon-shaped Keratitis.—In this form of keratitis there is a grayish band of opacity extending transversely across the cornea in the portion exposed by the palpebral commissure. Its surface is dry, and there is no vascularity, though the eye is irritable. The disease occurs most frequently in glaucomatous eyes. Cardiac and renal affections are said to be among the causes. Nuel found hyaline degeneration of the cells of Bowman's membrane, which may become the seat of calcareous concretions (calcareous keratitis). These are also sometimes found after the blebs of bullous keratitis or in old maculæ.

After the use of lotions containing acetate of lead in cases with ulcerations of the cornea, a dense white opacity has frequently been found beneath the epithelium. It is usually considered to be an insoluble precipitate of a lead salt, possibly an albuminate, but it is said that in some recent examinations of such patches no lead could be found. However that may be, the fact remains that lead will produce such opacities, and it should never be used when there is a chance of meeting with abrasions of the cornea.

Punctate Keratitis.—This term is frequently applied to deposits on Descemet's membrane, a symptom of uveitis, but there is also a superficial punctate keratitis characterized by small fairly distinct yellowish spots, with a diffused haziness due to œdema. Exposure to intense cold is said to be a cause, and the disease has also been observed in connection with influenza. The prognosis is favorable.

Interstitial or Parenchymatous Keratitis.—This variety of keratitis affects the deeper layers of the cornea. It is of endogenous origin and is due to syphilis, rheumatism, gout, tuberculosis, or some unknown dyscrasia. In a large proportion of cases (according to Horner, sixty-six per cent), syphilis, generally inherited, is the cause. This form occurs most frequently in subjects between five and twenty-five years of age, though it is occasionally met with before or after these limits. There is a deep haziness of the cornea, more or less concealing the pupil, and this haziness, when examined by oblique illumination and with a magnifying-lens, is seen to consist of minute interstitial spots which increase in number and coalesce, giving to the cornea the characteristic "ground-glass" appearance. There is a pericorneal vascular zone of moderate intensity. Vessels invade the cornea from its margin in loops, and salmon-colored patches appear, formed of capillaries so minute and so condensed as to give the impression of hemorrhages. The whole cornea may become vascular. Sometimes an interstitial gumma occurs as a rather well-defined grayish patch somewhat resembling a small abscess. Interstitial yellowish-white patches have been described as tuberculous deposits.

The anterior surface of the cornea may remain clear over the deep opacity, or it may present the appearance of having been disturbed by a number of minute punctures involving only the epithelium. There is often iritis. There is usually no tendency to abscess or ulceration. Under proper treatment the opacity clears away and the vessels disappear in the course of weeks or months, but there is likely to remain more or less disturbance of vision resulting from a slight permanent opacity and from the irregular astigmatism caused by alteration in the corneal curve. The hereditary cases are frequently marked by such signs of syphilis as the sunken nose bridge, enlarged cervical lymph nodes, periosteal nodes, scars at the angles of the mouth, etc., but particularly by the deformed incisor teeth described by Hutchinson and known by his name. All of the incisors and, as has lately been shown, even the molars may be more or less abnormal, but the typical deformity is that of the two middle upper incisors, which are narrower at the

Fig. 290.—Hutchinson Teeth.

edge than at the base ("peg-shaped") and have notched margins. (Fig. 290.) The acquired form is comparatively rare, but is occasionally met with.

Tuberculous or Scrofulous Interstitial Keratitis.—This variety of keratitis closely resembles the syphilitic in its local manifestations, and can often be differentiated only by the history and concomitant symptoms.

A denser, more localized, and more whitish opacity, dependent upon deep infiltration of the cornea and generally progressing from the margin, is sometimes met with in patients who do not give a syphilitic history, but who are subjects of rheumatism or gout or of some dyscrasia that is difficult to determine.

Sclerosing Keratitis.—Sclerosing keratitis is characterized by the appearance of bluish-gray patches of opacity, usually at the corneal margin, where they present the appearance of an encroachment on the part of the sclerotic. There may be little or no irritation or inflammatory symptoms, and the disease has rather the character of a degeneration. It is an affection of advanced life. A somewhat similar condition sometimes results from extension of inflammation to the cornea in sclero-choroiditis.

Striped Keratitis.—This form of keratitis is met with most frequently after cataract extraction, though it may occur after other wounds and in some cases of sloughing keratitis. After the operation for extraction it appears, soon after closure of the wound, as a series of grayish stripes deeply situated and extending at right angles to the direction of the wound, and is the result of the pressure of a large lens in escaping or of manipulations in clearing the anterior chamber of cortical masses. The former custom of irrigating the anterior chamber with bichloride solution was responsible for many cases. Nuel attributes it to cracks in the membrane of Descemet and œdema of the corneal tissue. It is not of serious import.

Arcus Senilis (Gerontoxon).—Arcus senilis is a rim of opacity near the corneal margin; it occurs in old people. It commences as an arc at the upper and the lower margins, where it remains the broadest, but may extend around the whole circumference. (Annulus senilis.) There is always a narrow rim (about 1 mm.) of clear cornea between the opacity and the sclerotic. It sometimes appears in people of middle age, particularly in certain families. It was formerly thought to be fatty and to be associated frequently with fatty degeneration of the heart, but is now considered to be the result of hyaline degeneration. Except for the unpleasant suggestion of old age, it is harmless and does not interfere with the cicatrization of operative wounds.

Descemetitis.—The term "Deep Punctate Keratitis" or "Descemetitis," until lately in general use, is now considered a misnomer, as the cornea is not necessarily inflamed. It is a symptom of uveal inflammation. There are minute dots of opacity, best seen by oblique illumination, on the posterior surface of the cornea. These dots represent deposits from exudations suspended in the aqueous humor, in cases of inflammation of the iris, ciliary body, or choroid, and particularly in cases of serous iritis. They are generally deposited in the form of a triangle, with its base at the lower margin of the cornea and its apex toward the centre. The microscope shows cells, fibrous matter, and pigment spots. According to H. Snellen, the dots consist largely of bacilli.

Conical Cornea (Kerato-conus).—The central portion of the cornea, in this abnormality, becomes thin and, losing its resistance, yields to the intra-ocular pressure and projects forward in the form of a cone, while the peripheral portions are flattened. This gives rise to a high degree of astigmatism, and seriously impairs vision, though the cornea remains clear, or, in advanced cases, becomes hazy at the point of the cone. Spontaneous rupture never occurs, as the intraocular pressure is reduced by transudation of aqueous humor through the thinned cornea. In well-marked cases the deformity is plainly seen upon ordinary inspection, particularly in profile (Fig. 291), but in the early stages expert examination with the ophthalmoscope, Placedo disc, ophthalmometer, or shadow test, may be required to detect it. The distortion of the image of window bars on the cornea may show it. It usually commences in early adult life, between fifteen and thirty, and, after slowly increasing for a time, comes to a standstill. Its etiology is unknown.

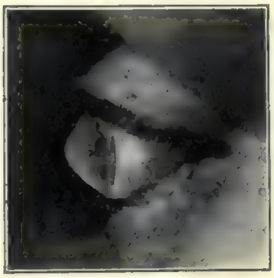


FIG. 291.—Conical Cornea. (May.)

Congenital Anomalies.—Localized opacities (*maculæ*) of the cornea are met with. An opacity at the periphery may give the impression of an encroachment on the part of the sclerotic.

Dermoid Cysts.—Dermoid cysts and malignant growths at the margin of the cornea have been referred to under diseases of the conjunctiva.

Kerato-Globus (buphthalmos, hydrophthalmos, infantile glaucoma).—This abnormality of the cornea is usually, though not invariably, congenital and increases during early childhood. The cornea is distended and greatly enlarged in all its dimensions, and of rounded form, from giving way to intra-ocular pressure. The sclerotic may also be involved (buphthalmos), and, when this is the case, it is abnormally thin and has a bluish tinge from the choroidal pigment seen through it. The anterior chamber is deep, and the lens is often dislocated. There is not often useful vision. According to some authors the disease originates in choroiditis.

Corneal Staphyloma.—This abnormal condition is sometimes congenital.

Microcornea.—In microcornea the cornea is imperfectly developed, and small in all its dimensions. If the whole ball is in the same condition we have microphthalmos.

Injuries of the Cornea.—A superficial wound of the cornea—a mere abrasion of the epithelium—will, if not infected, heal without leaving a mark, though it is sometimes very painful. Such an injury is often inflicted by the finger-nail of an infant. In rare cases the loss of substance is replaced by epithelium which seems to be imperfect and sloughs off, and this may occur several times and give rise to what is known as relapsing ulcer. If the wound is infected, either by the object that inflicts it or subsequently by bacilli in the conjunctival sac, a sloughing keratitis may result. Small foreign bodies, such as particles of iron or stone or coal or railroad cinders, frequently lodge in the cornea, and its transparency and the dark background of the iris may make them difficult to detect. They should be searched for in front of a window, or, better still, by oblique illumination in a dark room, and with a magnifying-lens. Grains of powder, being aseptic, usually cause comparatively little reaction. Penetrating wounds, if of considerable size, cause a gush of aqueous humor and a prolapse of the iris, and are likely to be complicated with injury of the lens. A wound of the cornea extending into the ciliary body, the "danger region," suggests danger of sympathetic ophthalmia and may necessitate enucleation. Burns with acids or alkalis, if they involve the deeper layers of the cornea, cause permanent opacity which often destroys sight. Injury of the cornea by the hairs of caterpillars is referred to as ophthalmia nodosa in the discussion relating to conjunctivitis (page 582).

The common results of diseases and injuries of the cornea are opacities and staphylomata. Vision is often disturbed by changes in the corneal curvature, even when they are not associated with much opacity. Rarely, a fistula may result from the perforation of an ulcer.

Opacities of the Cornea.—These result from inflammatory infiltration, ulceration, or traumatic injury. A superficial haze involving only the anterior layers will usually clear away, but, when deep loss of substance necessitates the formation of new tissue, the latter has not the transparency of the normal corneal tissue, and a permanent opacity results. A slight cloudiness of the cornea is called a nebula, and patches of opacity are called maculæ. A dense white opacity resulting from loss of substance is a leucoma, and, if the iris is adherent to it, an adherent leucoma.

The tension of the cornea, resulting from intra-ocular pressure in glaucoma and obstructing the lymph streams, causes an œdema and a peculiar misty opacity.

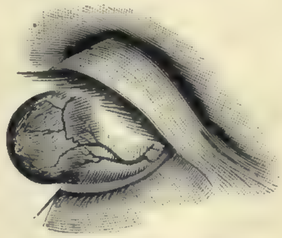


Fig. 292.—Corneal Staphyloma. (Noyes.)

Staphyloma.—Staphyloma, or bulging of the cornea, follows an extensive loss of tissue by ulceration, or sloughing with prolapse of the iris. The altered iris, remains of corneal tissue, and inflammatory exudation form a membrane with deficient resistance, which yields to intra-ocular pressure and bulges (Fig. 292). It is usually rounded, opaque, and either of a grayish tint or more or less colored by iris pigment. Sometimes this membrane, when it consists chiefly of iris, is very thin and has the appearance of a purple grape. The anterior part of the sclerotic may also be distended. (Corneo-scleral staphyloma.)

Fistula of the Cornea.—This is rarely observed. It is usually described as occurring in connection with inclusion of the sphincter of the iris in a perforation, but I have seen two cases, both of long standing, in which there had been no prolapse of the iris. In these cases, at least, it seems probable that the edges of the opening had become lined with epithelium. There is a constant leaking of the aqueous humor, and the eyeball is soft. Such leakage sometimes occurs from an imperfectly closed wound after cataract extraction.

TREATMENT.—In acute superficial keratitis a mixture composed of atropia gr. iv., boric acid gr. x., and distilled water fl. ℥ i., will be found serviceable. If there is much conjunctivitis, alum gr. ss. may be added to the mixture. In some cases, iced cloths may be used in the early stages, and hot stupes later. If ulcers prove obstinate, their healing is hastened by touching them with pure carbolic acid on a few strands of absorbent cotton twisted on the end of a cotton-holder or a pointed wooden toothpick. Deeper and more chronic ulcers may be scraped with a spud (Fig. 293) or touched with the actual cautery.

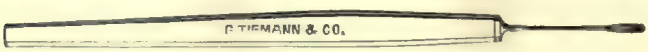


FIG. 293.—Spud.

Absorption and relapsing ulcers are treated in this way. Cocaine makes the procedure painless. If keratitis is due to exposure of the cornea from lagophthalmos or exophthalmos, as in goitre, tarsorrhaphy should be performed. The treatment of phlyctenular keratitis has been discussed under Phlyctenular Conjunctivitis, and the treatment of the vascular form of keratitis in trachoma under the latter head. Sloughing ulcers are treated with atropia, a compress bandage, and hot stupes. The compress is removed three or four times a day, the eye is thoroughly cleansed with an antiseptic solution (boric acid gr. x. to the fl. ℥ i., or bichloride of mercury or potassium permanganate 1 to 5,000), and hot fomentations are applied continuously for from twenty minutes to one hour at a time, by means of pads of absorbent cotton wet with water as hot as can be comfortably borne, and frequently changed. The temperature of the water is maintained by an alcohol or gas flame or by frequent renewal. If improvement is not evident in twenty-four hours, the ulcer should be lightly but thoroughly touched with the actual cautery (galvano-cautery, or a probe, a steel knitting-needle, or a heavy strabismus-hook heated in an alcohol flame). I have been using for many years a small cautery iron (Fig. 294). In the deep ulcer, the whole surface, all the sloughing area, is cauterized. A few drops of a one-per-cent or two-per-cent solution of fluorescein applied to the cornea will show the extent of the region involved by giving a greenish tinge to the parts of the cornea deprived of epithelium. (Two per cent of fluorescein can be dissolved in a three-and-a-half-per-cent solution of carbonate of soda.) In the ulcus serpens the outer margin of the sloughing ring is cauterized. The slough can be nicely


FIG. 294.—Corneal Cautery Iron.

cleared away, and the ulcer stimulated by wiping with hydrogen dioxide on a small pledget of absorbent cotton. In hypopyon with extensive parenchymatous slough the Saemisch incision (see Operations, page 617) will sometimes save useful vision in an apparently hopeless case. The crescentic ulcer is treated in the same way, or by application of carbolic acid.

Bullous keratitis usually occurs in eyes whose usefulness has been impaired by previous iridocyclitis or glaucoma, and in which not much vision is left. Lancing of the vesicles, atropia, hot stupes, occlusive bandages, etc., may give relief. Iridectomy is indicated if the eye is glaucomatous, and eserine or pilocarpine should be substituted for atropia. If the condition is permanent or if relapses occur, and if there is continued pain with no vision, the radical treatment is enucleation.

Keratomalacia is the result of general conditions, and not much can be done for it locally. Atropine, hot stupes, and compresses may give some relief, and tonics and stimulants should be administered as required.

Dendritic keratitis is also most influenced by general treatment—particularly by large doses of quinine. Atropia, hot fomentations, and compresses are useful. In obstinate cases, scraping of the ulcers and the use of the actual cautery are recommended.

Filamentous keratitis is relieved by removal of the filaments and the use of antiseptic washes. Methyl blue, one per cent, is a favorite application with some surgeons.

Neuroparalytic keratitis and herpes zoster require general treatment. Quinine in large doses is sometimes useful. Locally, frequent cleansing with antiseptic solutions, atropia, and careful occlusion with compresses are required. In persistent cases, tarsorrhaphy may be considered.

Striped keratitis usually disappears after the wound has thoroughly cicatrized, and does not require special treatment.

Ribbon-shaped keratitis usually occurs in eyes otherwise impaired. If there is sight enough to make treatment worth while, it may sometimes be improved by scraping away the opaque portion of the cornea with a Graefe knife or keratome. The same treatment is applied to lead opacities.

In so-called keratitis punctata treatment is directed to the disease of the iris and choroid.

The hereditary form of interstitial keratitis is a tertiary lesion, and requires a prolonged course of mercury and iodides. "Mixed treatment" is generally used. Iron, quinine, and cod-liver oil are useful in many cases. The syrup of the iodide of iron is a good preparation of iron, and may be combined with potassium iodide and bichloride. As the iris is often involved, atropia is important.

In syphilitic, rheumatic, gouty, and tuberculous keratitis, the remedies appropriate to these general diseases are relied upon. Locally, atropia and hot stupes are used.

Superficial opacities usually diminish more or less in the course of months or a year, and their disappearance may be hastened by stimulating applications, such as a solution of zinc sulphate (gr. ss. to gr. i. in distilled water fl. ℥ i.) or bichloride of mercury (1 to 5,000), yellow-oxide ointment (gr. $\frac{1}{4}$ to gr. ss. to ʒ i.), or calomel dusted on the opacity from a camel's-hair brush. It has recently been recommended to stimulate lymphatic absorption by the application of dionin, two to five per cent, or the subconjunctival injection of normal salt solution.

The pain in corneal abrasions is relieved by atropine and cocaine and a compress bandage.

Foreign bodies are removed, under cocaine, with the spud (Fig. 292). Grains of powder may be burned out with a fine point of the galvano-cautery. The edges of penetrating wounds can generally be held in apposition by a compress, after careful cleansing and sterilization and the replacement or abscission of the prolapsed iris. If the wound gapes a fine superficial suture may be applied, or, as has been recently recommended, the surrounding conjunctiva may be dissected up with scissors and temporarily sutured over the cornea.

In conical cornea the sight can sometimes be much improved, though not brought up to standard, by careful correction of the refraction, usually with sphero-cylinders of high power, or by a stenopaic slit. Myotics, by diminishing the intra-ocular pressure, tend to prevent an increase of the deformity, and, at the same time, may improve vision by narrowing the pupil. Iridectomy is sometimes performed to diminish intra-ocular tension, or to form an artificial pupil behind the less disturbed part of the cornea. Radical treatment attempts to diminish the cone by the knife or cautery.

Staphyloma is treated by operative procedures. (See page 618.)

In cases of permanent localized central opacity, vision may be improved by forming an artificial pupil behind a clear portion of the cornea, though the visual result is likely to be disappointing on account of the high degree of spherical aberration of the periphery of the cornea and lens. Sphincterectomy is often more satisfactory. (Page 620.)

In kerato-globus an iridectomy is sometimes indicated to diminish tension and prevent the increase of the bulging. Enucleation or abscission is often required.

Good results have recently been claimed for mercurial treatment of the choroiditis.

VIII. DISEASES OF THE IRIS AND CILIARY BODY.

Iritis.—It is estimated that at least sixty per cent of cases of iritis are of syphilitic origin. Next in order of frequency as to cause comes rheumatism; and other causes are gout, diabetes, gonorrhœa, malaria, traumatism, and new-growths. Iritis also occurs after various infective fevers, such as smallpox, typhoid, pneumonia, meningitis, and influenza, and rare cases in which no cause can be assigned are called idiopathic.

Iritis commences as a hyperæmia with a moderately distinct pericorneal zone, discoloration or loss of brilliancy of the iris, a sluggish and more or less contracted pupil, ocular and periorbital pain, lachrymation, photophobia, and some indistinctness of vision. Later the pericorneal zone is more decided, the aqueous humor is turbid, the iris is dull and sometimes swollen, and enlarged vessels or hemorrhagic spots can be seen by oblique illumination; the pupil is contracted and dilates irregularly, if at all, when shaded, and there are adhesions of the iris to the capsule of the lens quickly shown by the action of atropia, which dilates the free portions of the pupillary margin while the attached portions remain fixed (Fig. 295). If the whole of the pupillary margin is adherent, we have annular synechia, and the anterior chamber is shut off from the posterior (exclusion of the pupil). The peripheral portions of the iris are then bulged forward by the pressure of the aqueous humor behind them, and the pupil seems at the bottom of a depression (Fig. 296) (crater-shaped iris, iris bombé). This confining of the aqueous humor in the posterior chamber and mechanical closure of the filtration-angle of the anterior chamber cause increased intra-ocular tension. When the pupil is filled with exudation it is said to be occluded. Adhesion of the whole of the posterior surface of the iris to the lens capsule is called total synechia. In cyclitis there is a more pronounced pericorneal zone, and the ciliary region is very sensitive to pressure through the lid. It may be general or localized. It generally occurs in connection with iritis (irido-cyclitis).

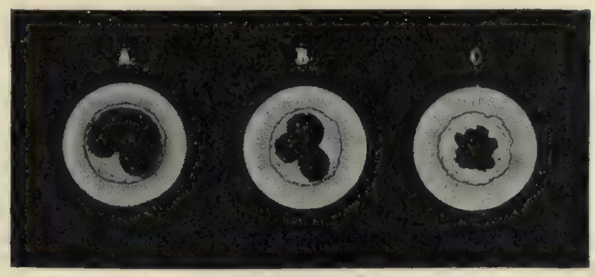


FIG. 295.—Posterior Synechiæ in Iritis. (Noyes.) *A* shows single synechia and *B* three synechiæ. In *C* the synechia is circular in shape.

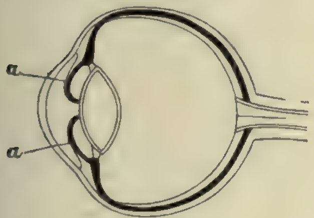


FIG. 296.—Iris Bombé. (Noyes.) *a*, *a*, The iris is adherent at the pupillary margin and bulges.

It might be logical to consider iritis under the heads of plastic iritis, serous iritis, and purulent iritis, but it is certainly more convenient to retain the subdivisions which have an etiological basis—as, for example, syphilitic iritis, rheumatic iritis, etc.

Syphilitic Iritis.—By far the most common form of plastic iritis is the syphilitic variety, which occurs as a secondary or a tertiary lesion. As a secondary lesion it appears within nine months of the primary infection, and is frequently accompanied by other secondary manifestations, such as tonsillitis, early cutaneous eruptions, enlarged cervical lymph nodes, etc. It is of an adhesive type, with a tendency to the rapid formation of firm adhesions. If these are broken by the action of mydriatics their position is marked by uveal deposits on the anterior capsule. Oblique illumination shows condylomata in the form of small nodules of a yellowish-brown color, not more than 2 mm. in diameter, surrounded and sometimes traversed by fine vessels. They are transient, but probably occur at some stage of every case. At first one eye only is usually affected, but the other is, in most cases, involved subsequently. The tertiary form appears months or years after the primary lesion, and often in connection with other tertiary symptoms, such as gummata of the muscles or viscera, periosteal nodes, ozæna, etc. The ciliary region is involved in many cases (syphilitic irido-cyclitis). Gummata sometimes appear as large rounded reddish-yellow or grayish masses, most frequently at the pupillary or the attached margin of the iris. When occurring in the ciliary region they may cause a ciliary staphyloma.

Iritis of the tertiary form occasionally occurs, generally in connection with interstitial keratitis, in children who are subjects of hereditary syphilis. It also occurs in older subjects as a hereditary lesion at about the age of twenty-one, —most frequently as irido-cyclitis, which may be either plastic or serous in character. In many cases the patients appear to be in excellent general health, with no other symptoms of syphilis.

Rheumatic Iritis.—In rheumatic iritis the adhesions are not so firm, and are more readily torn away or stretched and less likely to leave pigment deposits on the capsule, and cyclitis is not so common. Pain and photophobia may be severe. It often occurs in connection with acute articular or subacute muscular rheumatism; or may occur independently, but in patients who have been subjects of rheumatism in some form.

Gouty Iritis.—Gouty iritis resembles closely the rheumatic. There is a marked tendency in both to recurrence, which is not so common in the properly treated syphilitic form.

Gonorrhœal Iritis.—Gonorrhœal iritis resembles the rheumatic, and is usually associated with synovitis. It may occur either in the early or in the gleety stage of gonorrhœa.

Diabetic Iritis.—The subjects of diabetes mellitus are especially liable to iritis, particularly after wounds, as in cataract operations. It is usually of the plastic form.

Tuberculous Iritis.—This form of iritis is comparatively rare, and occurs nearly always in patients under twenty years of age. It is characterized by the appearance of multiple small reddish-yellow or grayish nodules, from 1 to 6 mm. in diameter, or of a larger solitary growth of rounded or oval form. There are sometimes also tuberculous deposits in the cornea, and particles of disintegrated nodules may collect in the lower angle of the anterior chamber, the condition resembling hypopyon. In some cases the smaller nodules are absorbed, the eye retains useful vision, and the patient remains in good health; but too often the case terminates in general tuberculosis or meningitis. The larger growth may increase in size until it fills the anterior chamber and perforates the cornea.

Serous Iritis.—In serous iritis there is less tendency to plastic exudation, and the pupil may even be slightly dilated. The ciliary body is nearly always affected, and frequently the whole uveal membrane (iris, ciliary body, and choroid) as well. Its most characteristic symptom is the deposit, on the posterior surface of the cornea, of small dots of exudate which have been suspended in the aqueous humor ("keratitis punctata").

Spongy, fibrinous, or gelatinous iritis is a term employed in cases in which an excessive exudation coagulates in the anterior chamber, which it may fill. The picture presented may have a striking resemblance to that of a dislocated cataractous lens.

Purulent Iritis.—Purulent iritis may be the result of exogenous infection from septic wounds or sloughing keratitis, or of endogenous (metastatic) infection from various infective diseases. Usually the ciliary region is involved, and frequently the whole uveal tract (panophthalmitis), when the eyeball is converted into an abscess. Pus suspended in the aqueous humor is deposited at the bottom of the anterior chamber (hypopyon).

Traumatic Iritis.—Traumatic iritis, if the result of a contusion without rupture of the ball or of injury by a sterile instrument, is usually of a rather mild plastic type. If caused by a septic wound, it is purulent, and the inflammation is likely to extend to the rest of the uveal membrane. The slight iritis, with delicate synechiæ, that occurs nearly always after successful iridectomy or cataract extraction, illustrates the former; and the cases of infection after these operations the latter.

Quiet or Insidious Iritis.—This term is applied to occasional cases without pain or other symptoms of inflammation, and in which the patient complains only of loss of vision. Extensive synechiæ may be found. It occurs in anæmic and poorly nourished subjects.

Sympathetic Irido-cyclitis (Sympathetic Ophthalmia).—This form of inflammation occurs in a sound eye as the result of a similar inflammation of the other, which, in a large proportion of cases, is caused by an infectious traumatism of the ciliary region or by the presence of a foreign body in the eyeball. Its pathogeny is not determined. A few cases have been reported of sympathetic ophthalmia from an irido-cyclitis due to other causes, such as the presence of an intraocular tumor or a dislocated lens. Sympathetic ophthalmia usually commences in from three to six weeks after the injury, though sometimes a little earlier or very much later, even months or years. It is generally of the plastic form, but occasionally is serous in character. The first symptoms are commonly a haziness of objects, photophobia, and a pericorneal zone. Later, in the plastic form, there is a free exudation of lymph, with firm adhesions and occlusion of the pupil. The pain is usually not so severe, in proportion to the extent of the disease, as in other forms of iritis, but there may be decided ciliary tenderness. In the early stages there is increased intra-ocular tension, but later the eye becomes soft. A large proportion of cases result in complete blindness. In the serous form the approach of the disease is more insidious and the symptoms are those described under Serous Iritis, with probably a greater tendency to the formation of adhesions.

Sympathetic irritation is an affection distinct from sympathetic ophthalmia, and is a form of neurosis. It occurs usually later, sometimes years after the injury. The injured eye is generally sensitive to the touch, and in many cases there is ossification of choroidal exudates which may be felt through the sclerotic at the posterior part of the globe. The sympathizing eye is irritable, watering, and photophobic, and the vision is indistinct. Pain, which may be intense, is felt in the ball, orbit, temple, and forehead, and is increased by an attempt to use the eye, which also causes pain in the other eye. There are often general nervous irritation and exhaustion, but there is no iritis. The symptoms almost invariably promptly disappear on enucleation of the injured eye.

Mydriasis.—Mydriasis is a persistent dilatation of the pupil. It may be due to paralysis of the sphincter (third pair) or to irritation of the dilating fibres under control of the sympathetic.

Myosis.—Myosis is a contracted state of the pupil due to irritation of the oculo-motor or to paralysis of the sympathetic.

Hippus.—Hippus is a spasmodic, rhythmic contraction and dilatation of the pupil, independent of the light reflex. It is very rare, and is generally associated with some disease of the nervous system.

Mydriasis and myosis are often due to the action of certain drugs. These conditions may be symptoms of some general neurotic affection.

Iridodonesis.—Iridodonesis (trembling of the iris) is a waving motion of the iris, noticed when the ball is quickly moved. It is due to loss of the support of the lens, and is a symptom of absence or dislocation of the latter. It is always present after cataract extraction, unless prevented by adhesions.

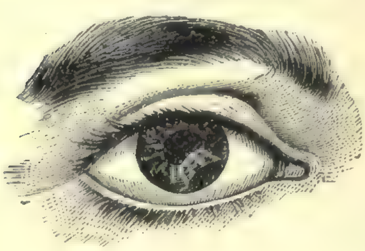


FIG. 297.—Iridodialysis. (Noyes.)

Injuries of the Iris.—Contusions of the ball often cause rupture of the iris. The most frequent is a separation of its attached border (iridodialysis). There is usually a collection of blood in the anterior chamber (hypæmia) and when this is absorbed there is seen at the periphery of the iris an opening which, like the pupil, seems black to ordinary inspection, but shows the red fundus reflex when examined with the mirror. (Fig. 279.) The corresponding segment of the iris loses its power to dilate, and the pupil is irregular. Less frequently the sphincter is ruptured, when a notch can be seen in the margin of the pupil, or there may be a number of ruptures (multiple rupture) (Fig. 298), and the pupil is irregular and permanently dilated. Still more rare are radiating ruptures in the body of the iris. (Harlan, Trans. Am. Oph. Soc., 96.) Contusion without rupture of the iris sometimes causes mydriasis by paralysis of the sphincter. It is usually accompanied by paralysis of accommodation. Punctured wounds of the iris generally involve the lens, and foreign bodies passing through it are lodged in the lens, the choroid, or the vitreous humor. In considerable wounds of the cornea the iris prolapses and appears as a small black tumor on the surface of the cornea. It is often distended by aqueous humor, which gives it the form of a cyst.

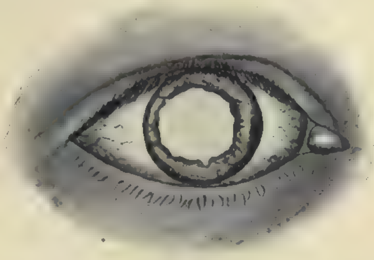


FIG. 298.—Multiple Rupture of the Iris. (Harlan.)

Tumors of the Iris.—Melanomiæ are small dark growths in the iris stroma; they are usually congenital. They are generally harmless, but are said occasionally to become the seat of melanotic sarcoma.

Cysts of the Iris.—Iris cysts are of two kinds: the serous and the dermoid. The former appear as translucent vesicles commencing at the angle of the anterior chamber. The latter have atheromatous contents. Both are developed in the iris stroma, and are lined with epithelium. Nearly always they have their origin in corneal or conjunctival epithelium or cilia bulbs. A few cases of congenital dermoid cysts have been reported. Iris cysts tend to increase in size, and cause glaucomatous symptoms and destruction of the eye. Even sympathetic ophthalmia seems possible.

Gummatous and Tuberculous Tumors.—A few instances of such tumors have been recorded.

Sarcoma.—Sarcoma, most frequently melanotic, is occasionally met with. The tumor is of a brownish color, and sometimes vessels can be seen upon it. It may be confined to the iris for months or years, but sooner or later it perforates the cornea and extends to the neighboring tissues. Sarcoma sometimes also develops in the ciliary body, and growing behind the iris becomes adherent to it and drags it from its attachment (iridodialysis). It may be primary, which is rare, or it may extend from the choroid or occur metastatically. Repeated hemorrhages into the anterior chamber (hypæmia) have been noted in some cases of sarcoma of the iris or of the ciliary body.

Vascular Tumors and Tumors Due to the Cysticercus.—A few cases of such tumors have been noted.

Congenital Anomalies of the Iris.—Irideremia or aniridia, complete absence of the iris, is occasionally met with. In a large proportion of cases it is accompanied by other defects, such as *microphthalmos* (small eye), *coloboma of the choroid*, cataract, or dislocated lens. ("Irideremia"—Harlan, Trans. Phila. College of Physicians, 1883.)

Coloboma.—Coloboma is the absence of a segment of the iris, giving the appearance as if an iridectomy had been performed.

Corectopia.—Corectopia is a displacement of the position of the pupil.

Polycoria.—In polycoria there are several pupils. Persistent pupillary membrane results from the failure of the embryonic capsulo-pupillary membrane, that surrounds the lens for its development in early fœtal life, completely to disappear. Opaque threads are stretched across the pupil, and these threads are distinguished from inflammatory exudations by the fact that they are not attached to the pupillary margin, but pass over from the anterior surface of the iris.

Ectropion of the Uvea.—Ectropion of the uvea is a projection of the pigmentary layer of the iris beyond the margin of the pupil, in the form of little brown nodules, similar to the normal condition in the horse.

Treatment of Diseases of the Iris.

The most obvious and important indication in the treatment of all cases of iritis is to prevent adhesions to the anterior capsule, or, if possible, to break them when formed, by means of a mydriatic. The best mydriatic in most cases is atropia, and a solution of gr. iv.–fl. ℥ i. is a convenient preparation. In the early stages it should be used three or four times a day. When there are numerous or firm adhesions a stronger solution (gr. viii.) may be applied by the surgeon every ten minutes for an hour, in addition to the regular applications made by the patient or nurse. When the stronger solution is used, not more than two drops should be applied at a time, while the punctum is everted and pressure is made upon the canaliculus to prevent the passage of the fluid into the throat. The addition of cocaine promotes the absorption of atropia.

Prolonged use of atropia in certain persons of special susceptibility produces a form of conjunctivitis (atropia conjunctivitis) characterized by enlargement of the follicles in the conjunctival folds and an erythematous inflammation of the skin of the lids. Hyoscine (gr. ss. to gr. ii. to fl. ℥ i.) is said to be efficient in some cases in which atropia fails. As it is an active poison, it should be handled with care. When the pupil is once well dilated, the mydriatic may be used less frequently. In some cases of irido-cyclitis with increased tension mydriatics may be harmful. In such cases paracentesis of the cornea is useful. Local bleeding, either by the application of three or four Swedish leeches to the temple or by means of the Heurteloup artificial leech, often gives marked relief, and the pupil will sometimes dilate under atropia after it when it has refused to do so before. Leeches should not be applied too near the lids, as they produce œdema and ecchymosis. Hot stupes, applied by means of absorbent cotton or a sponge wet with water as hot as can well be borne, relieve pain, diminish congestion, and promote absorption. Dry heat can be applied by absorbent cotton heated on the side of a can of boiling water, or by means of the small water-bag or the Japanese hot box, and is preferred by some surgeons. It is well to commence the treatment of acute iritis with a mercurial purge.

In syphilitic cases mercury is as important in general treatment as atropia is locally. Calomel (gr. $\frac{1}{4}$ to gr. $\frac{1}{2}$, or mass. hydrarg. gr. i. to gr. ii.) may be given every two or three hours until the gums are touched; or the action of the drug can be better controlled by inunction. About ʒ i. of the mercurial ointment is rubbed twice a day into the skin in places where it is thin. The abdomen, the inside of the thigh, the axilla, and the forearm are the localities usually chosen. When one region becomes irritated, the application should be made to another. It is well to cover the part afterward with a piece of flannel cloth, and, in the case of infants, the ointment may be spread upon the binder.

Subcutaneous or intramuscular injections of bichloride or biniodide are highly praised by some authorities. Inunctions or injections may often be repeated with advantage after they have been omitted for five or six days; and later "mixed treatment" may be substituted. If pain is severe, morphia may be required to induce sleep. The diet, except in debilitated persons, should be light and with little or no meat. A patient with acute iritis of any form is always a good subject for confinement to bed. In gummatous iritis, in addition to the above treatment, iodide of potassium should be given in increasing doses pushed to tolerance. The most convenient plan is to use a fifty-per-cent solution, and then, commencing with, say, twenty drops three or four times a day, to add one or two drops to each dose daily. A saturated solution is sometimes used, but its rapid crystallization makes it troublesome. Some patients will bear two or three drachms a day.

The local treatment of rheumatic and gouty iritis is much the same as that employed for the syphilitic variety. Generally mercury and the iodides in moderate doses may be useful, but large doses of salicylates are more efficacious. Alkaline waters may be used freely, and, in case of the gouty form, colchicum may be added, and strict injunctions as to diet and the avoidance of alcohol should be enforced. Diaphoresis by means of hot or vapor baths, packs, etc., or pilocarpine, is sometimes resorted to with advantage in obstinate cases, and dionin is often useful.

Tuberculous iritis requires atropia locally and the general treatment appropriate to tuberculosis. In iris bombé communication between the anterior and posterior chambers should be restored, after the acute symptoms have subsided, by iridectomy, which is also useful when chronic or recurrent iritis is kept up by synechiæ.

The treatment of sympathetic ophthalmia is chiefly prophylactic, as therapeutics accomplish very little when the disease is once established. Treatment, however, by atropia, hot stupes, and mercurialization has been partially successful in some cases. There is safety only in the removal of the injured or diseased eye before the other is involved. When inflammation is established in the sound eye, its progress cannot usually be checked by removal of the other one. Under these circumstances, if the injured eye is hopelessly blind, it is better to remove it; but if it retains, or is likely to regain, useful vision, it is possible that it may be eventually the better eye, and therefore it should not be sacrificed.

It is not possible to lay down any general rule as to when an injured eye should be enucleated. Wounds in the ciliary region—the "danger region"—are most likely to be followed by sympathetic ophthalmia; and if there is a considerable wound in that region, particularly one inflicted by an instrument of doubtful asepsis, with prolapse of the iris, loss of vitreous body, and no vision, it is safer to enucleate the eye at once. It is not worth while to run even a slight risk of total blindness for the sake of an eye that can never be either useful or ornamental. A small and aseptic foreign body lodged in the eye will occasionally become encysted and give no trouble; but, generally speaking, the presence of a foreign body that cannot be removed is an indication for enucleation. In most cases the presence of such a foreign body causes so much pain that the patient will readily consent to the operation. If it is decided, in a doubtful case, to attempt to preserve an injured eye, the other should be carefully watched for many months. When the stump of an injured eye continues to be tender on pressure, it should never be retained.

Sarcomata and cysts of the iris have been successfully removed by iridectomy, though the former often necessitate enucleation.

Nothing is likely to be gained by the removal of a tuberculous lesion, as it would be quite sure to recur. If it causes great pain, the eye should be enucleated; and if it is considered primary, enucleation may be done in order to remove a focus of infection.

Wounds of the iris occur in connection with wounds of the cornea and frequently also with wounds of the lens. If there is no prolapse, the iris is simply kept under the influence of atropia. If there is a hernia of the iris through the corneal wound, the protruding part should be disinfected and replaced with a spatula if possible, or cut off with scissors close to the surface of the cornea, and a compressive bandage then applied.

IX. OPERATIONS UPON THE CORNEA, SCLERA, AND IRIS.

Removal of Foreign Bodies from the Cornea.—The eye should be first thoroughly cocainized; then the upper lid should be raised, and the eyeball steadied by the fingers of the left hand, while the edge of the spud (Fig. 292) is inserted at the side of the foreign body and it is tilted out. Oblique illumination and a magnifying-lens are needed if the foreign body is very minute.

Curetting of ulcers is also done with the spud. The diseased tissue is thoroughly scraped away, and the eye is disinfected and closed with a compress and bandage. Fluorescein is useful in delimiting the diseased tissue.

In superficial shaving of the cornea, as in case of lead deposit or calcareous incrustation, the superficial layers are shaved off with a Beer or Graefe cataract knife.

Cauterization.—Cauterization is performed with chemical caustics, or with the galvano- or the actual cautery. Various chemical caustics are used, such as a fine point of nitrate of silver, or tincture of iodine or carbolic acid on a few strands of absorbent cotton twisted on the point of a wooden toothpick or fine probe. My preference is for the last, as it is least painful and is very efficient. It is used in full strength of the deliquesced crystals. Cocaine renders the application painless, and the subsequent reaction is not severe. A twenty-per-cent solution of zinc sulphate is said to be an efficient caustic in sloughing cornea.

A large strabismus-hook, or a steel knitting-needle heated to redness in an alcohol flame, answers very well for an actual cautery, and is more easily handled than the galvano-cautery. The small cautery iron is convenient. (Fig. 293.) In conical cornea most surgeons prefer to make a slight perforation of the anterior chamber, through which the aqueous humor oozes rather than spurts.

Paracentesis.—Paracentesis of the cornea is performed temporarily to relieve tension or to evacuate pus. Desmarres's paracentesis needle (Fig. 299) is a small

Fig. 299.—Paracentesis Needle.

triangular knife with a shoulder to prevent too deep penetration and injury of the iris or lens, but a Beer or Graefe cataract knife, or a small keratome, answers well enough. It is entered obliquely a little above the lower limbus, and should be turned slightly on its axis before withdrawal, in order to evacuate the anterior chamber slowly and thus lessen the chance of a spurt of aqueous humor and perhaps the occurrence of a hernia of the iris.

Saemisch Keratotomy.—This operation, which is employed in sloughing keratitis, consists in incising the cornea through the slough with a Graefe knife which is inserted through the sound cornea at one edge of the ulcer and brought out at a corresponding point on the opposite edge, after which it is made to cut its way out. In order to evacuate the aqueous humor slowly, the knife, before it does any cutting, is turned on its axis, while its back is pressed against the cornea. It is often necessary to reopen the wound, several times on successive days, with the probe point of the Weber canaliculus knife (Fig. 287).

Removal of Dermoids.—Dermoids at the corneal margin are removed by taking them up in conjunctival forceps and shaving them off with a Beer or Graefe knife. When small malignant growths are removed from this position, the base should be freely seared with the actual cautery. Larger ones, or such as have recurred, usually require enucleation of the eye.

Operation for Staphyloma.—A partial staphyloma, or one involving the cornea only, may be treated by excising a small elliptical flap, evacuating the lens, and allowing the wound to heal under a compressive bandage. A discission needle is passed through the top of the staphyloma, which is transfixed and incised on one side of the needle with a Graefe knife, and the excision of the flap is completed by a cut with scissors on the other side. Large total or corneo-scleral staphylomata require amputation or abscission. Critchett passed three or four large curved needles, threaded, behind the base of the staphyloma, and left them in position while he abscised the mass with a Beer's knife and scissors; and then, drawing the threads through, tied them (Fig. 300). The needles are usually inserted farther back than represented in the cut. In this way the vitreous body is better preserved during the operation than is possible by any other procedure. It has been objected that the sutures, or some of them, pass through the ciliary region; but if the staphyloma is an extensive one, they may pass behind the region. I have performed this operation very often, and have never met with any unpleasant results. If such should occur, the eye can still be enucleated, while, if all goes well, the vitreous humor makes a better filling for a stump than does any artificial substitute, and the result is much better than that of enucleation, particularly in the case of children, in whom the absence of the ball affects the development of the orbit and the side of the face. Abscission should be practised more generally than it is. To avoid the Critchett sutures, Knapp advises that the threads be passed through the conjunctiva and only the superficial layers of the sclera; and Wecker dissected up the conjunctiva around the base of the staphyloma and formed a "purse string" or "tobacco-pouch" suture through it only, this suture being drawn together after the abscission. Unless anæsthesia is very profound, it is more difficult to retain all of the vitreous body by these procedures than by Critchett's.

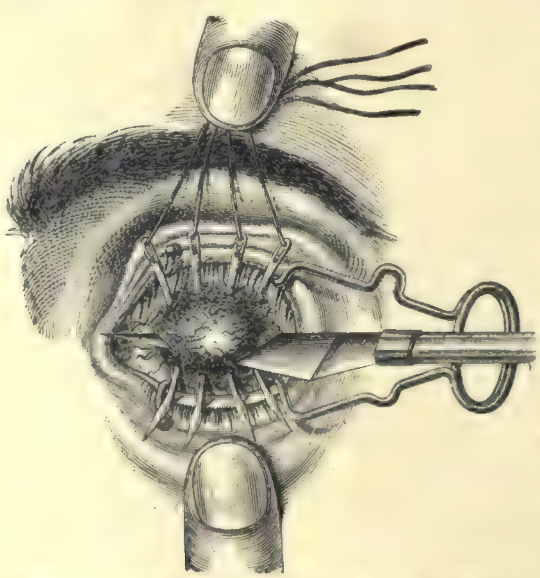


FIG. 300.—Critchett Abscission Operation. (Stellwag.)

Gaping wounds or perforating ulcers of the cornea may be covered by conjunctiva by dissecting it up around the cornea, drawing it over, and suturing. The wound or ulcer should first be thoroughly disinfected, and the ulcer scraped or cauterized.

Tattooing the Cornea.—For the tattooing of disfiguring white spots, or patches of partial opacity, associated with high irregular astigmatism, India ink is used. It is rubbed in a glass dish, with a 1:1,000 solution of bichloride and a spatula, to the consistence of a rather thin paste. This is placed on the part to be blackened, and oblique punctures are made through it, in the cocainized cornea, with a bundle of fine needles (Fig. 301); or the punctures are made first and the paste is rubbed in with a spatula or the finger. Careful asepsis

FIG. 301.—Tattooing Needles.

should be observed, and the ball should be steadied by pressure with the finger, as there is danger of tattooing the conjunctiva by the grip of the forceps. An imitation pupil tattooed in the centre of an opaque cornea sometimes effects a marked cosmetic improvement. The cornea has been tattooed in colors to imitate the iris.

Separation of Anterior Synechiæ.—Anterior synechiæ may be separated by making a small incision in the cornea with a broad needle or a Graefe knife, and introducing a blunt-pointed needle with which the adherent iris is freed from the cornea.

Transplantation of Cornea.—Various attempts have been made to transplant clear corneal tissue from the eye of one of the lower animals to an opaque human cornea, but without success. The graft always became opaque, even if it retains sufficient vitality to remain in position. Recently Zirm, of Olmütz, has succeeded in giving a man blind from corneal opacity sufficient vision to go about alone and to assist in light farm work. He accomplished this by grafting a section of the cornea of a boy whose eye was removed in consequence of an injury. The graft was removed with the corneal trepan, and preserved between two pieces of gauze wet with sterile salt solution and held over steam until it was actually needed; then it was placed in position in the opening made for it (also by the trepan) in the patient's cornea. Finally, it was retained in position by suturing the conjunctiva over it (*Medical Record*, New York, March 9th, 1907).

Iridectomy.—Iridectomy is performed for the formation of an artificial pupil (*optical iridectomy*), to restore the communication between the anterior and posterior chambers in exclusion of the pupil, to reduce intra-ocular tension in glaucomatous conditions, or as a preliminary to extraction of cataract. An optical iridectomy should be narrow, as the broad base of a wide coloboma, by exposing the periphery of the cornea and lens, causes a high degree of spherical aberration. An incision is made with a narrow keratome at the margin of the clear cornea, and the iris is seized at the pupillary margin with fine forceps or a blunt hook, drawn out, and excised with scissors close to the surface of the cornea. The blades of the forceps are introduced closed, and then are opened in the anterior chamber.

When there is sufficient clear cornea to admit of the procedure, better optical results are obtained by a *sphincterectomy—i.e.*, by cutting merely the pupillary margin. The margin of the pupil is caught in a blunt hook, drawn out, and cut off close to the hook, and the iris is replaced with a fine spatula. These operations can usually be performed under cocaine anæsthesia. Atropia and an occlusive bandage are used for five or six days.

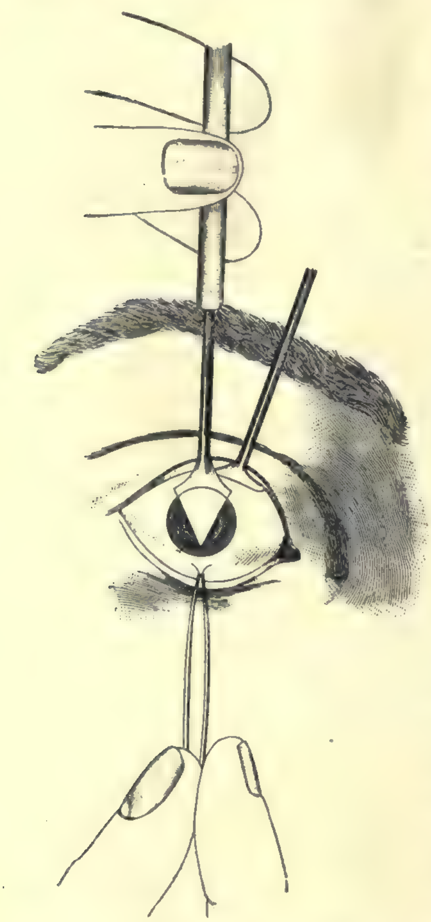


FIG. 302.—Corneal Incision in Iridectomy. (Norris.)

Iridectomy to reduce intra-ocular tension is much more easily and safely performed with the aid of general anæsthesia. A much broader segment of iris may then be excised, and it should be removed as close as possible to its attachment. The excision is usually done in the upper part of the iris, that excessive light may be shut off by the upper lid. The speculum is introduced, and the ball is steadied by forceps grasping the conjunctiva and subconjunctival tissue below the corneal margin. To reach the periphery of the anterior chamber the broad keratome is entered about 1 mm. above the edge of the clear cornea. Its blade is held parallel with the plane of the iris, and is pushed across the anterior chamber as far as practicable without bringing the point in contact with the posterior surface of the cornea (Fig. 302). It is then withdrawn slowly with the point slightly tilted, to avoid wounding the lens which comes forward with the escape of the aqueous humor. The fixation forceps is then entrusted to an assistant, and the operator inserts the iris forceps closed, pushes it forward close up to the pupillary margin, opens the blade slightly, seizes the iris, draws it out through the wound and, while making slight traction, excises it close to the surface of the cornea with two or three snips of the scissors held horizontally, or by means of a single cut with the scissors held vertically. The angles of the wound are carefully freed from iris with the spatula, and both eyes are bandaged until the wound has healed. The operated eye is kept bandaged for several days longer.

In iridectomy preliminary to cataract extraction the wound need not be so large or located so close to the periphery, and the iris may be excised with one cut of the scissors held perpendicularly to the corneal incision (Fig. 303). Slight pressure with the scissors held in this way assists in steadying the ball.

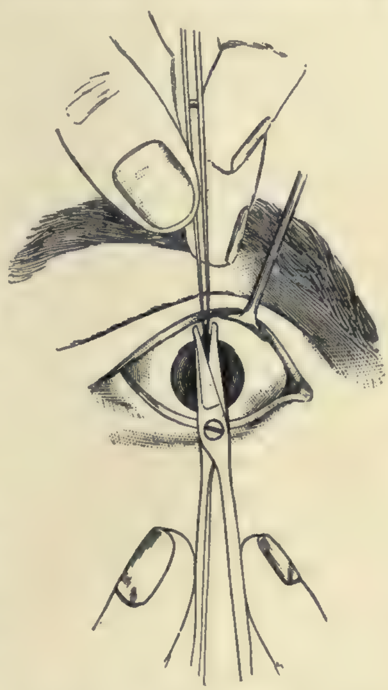


Fig. 303.—Excision of Iris in Iridectomy. (Norris.)

When the anterior chamber is very narrow, there is less danger of wounding the lens if the corneal incision is made with a Graefe knife. The knife should be a very narrow one, the incision should be made 1.5 mm. from the clear cornea, and the distance between the puncture and the counterpuncture should be not more than 6 or 7 mm.

When the anterior chamber is obliterated by pressure of the iris against the cornea, as sometimes happens in the excessive tension due to glaucoma or in exclusion of the pupil by an old iritis, it may be impossible to introduce the knife between the cornea and the iris. The incision may then be made by cutting from without inward with a small, sharp scalpel or a scarificator, until the anterior chamber is entered, as shown by the escape of aqueous humor, and by then enlarging the wound with a Weber canaliculus knife or probe-pointed scissors (Fig. 278).

Coreïysis or Synechtotomy.—Corelysis, or synechtotomy, is the detachment of posterior synechiæ. It is done with Streatfield's notched spatula, a fine probe, or a pair of toothless forceps. The spatula is passed into the anterior chamber through a wound in the cornea made with a broad needle, and is inserted between the lens and the iris at the point of adhesion, which is gently detached. The forceps is inserted in the same way and grasps the iris, which is drawn away from its attachment to the capsule. This operation has been practically abandoned.

Iridonchisis or Iridodesis.—By this operation the pupil, in a case of central opacity, was dislocated so as to occupy a position behind a clear portion of the cornea. An incision was made in the cornea with a broad needle, and the iris was allowed to prolapse, or was drawn into the wound with forceps or a blunt hook. In iridonchisis the iris was left to adhere by inflammation, and in iridodesis it was tied with a thread. The operation affords no advantages over iridectomy to compensate for the danger of iritis, and even of sympathetic ophthalmia, and it has therefore been abandoned.

Iridotomy.—Iridotomy is the simple incision of the iris without removal of a portion of its substance. Its chief application is in case of occlusion of the pupil after cataract extraction. The operation is also performed when the iris is drawn up and the pupil occluded, or when light is shut out by a dense curtain consisting of iris, inflammatory exudates, and lens capsule. The operation is performed with the Wecker forceps-scissors (Fig. 304), or with a narrow Graefe knife. An incision in the cornea, large enough to admit the scissors closed, is made with a small keratome. The scissors are opened in the anterior chamber, and the pointed blade is passed through the iris and the other parts in front of it, and the tissue is divided with one cut. If the iris retains its contractility, the wound gapes and leaves a clear pupil. Otherwise a second incision is made in such a manner as to form, with the first one, a V-shaped flap; or a narrow Graefe knife, with its cutting edge toward the iris, is passed through both the cornea and the iris. The incision is made by simply raising the handle of the knife. Dr. Ziegler, of Wills' Hospital, uses a Hay's knife needle, which he enters at the upper portion of the cornea, punctures the iris below, and makes an upward incision by a sawing movement. A second similar incision is made by inserting the knife at a point 6 or 7 mm. from the lower end of the first, and carrying it in a converging line until it joins the latter at its upper end. There is thus formed a flap which has the shape of an inverted V, and which contracts either at once or gradually. (Fig. 305, *a*, *b*, *c*.) Knapp performs iridectomy; he introduces a Beer's knife through the lower part of the cornea, incises the upper part of

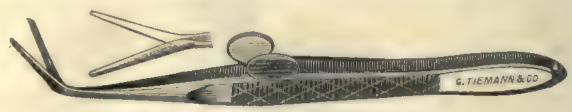


FIG. 304.—Wecker Forceps-Scissors.

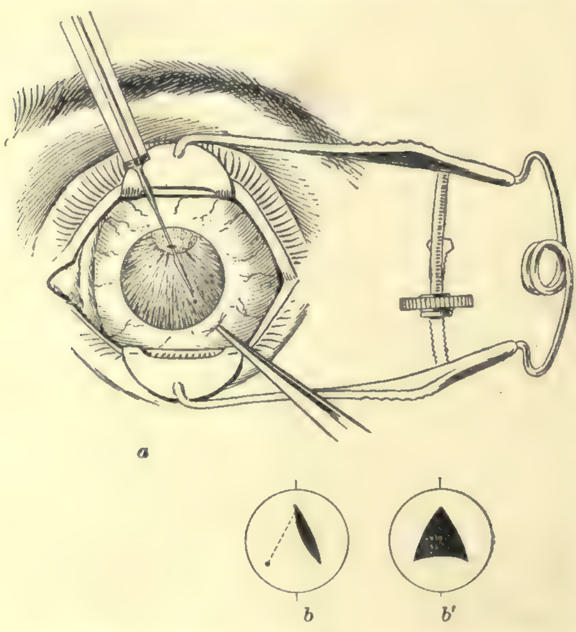


FIG. 305.—Iridotomy. (Ziegler.) In *a* the general features of the operation are shown; at *b* and *b′* are seen the resulting openings.

the iris with the point, catches the lower margin of the iris wound with a blunt hook, draws out a segment of the iris, and cuts it off.

Anterior Sclerotomy.—This operation is sometimes useful in glaucoma when, for any reason, as in the hemorrhagic form, iridectomy is impracticable. A narrow Graefe knife is inserted in the same way as in cataract extraction, but somewhat farther back in the sclera, and a cut is made as if to form a flap; but the incision is not completed, a broad bridge of sclera being left, with an incision at a distance of about 3 mm. on each side of it. (Fig. 306.)

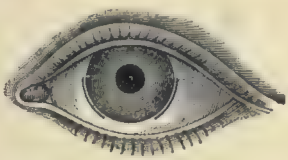


Fig. 306.—Anterior Sclerotomy. (Noyes.)

Posterior Sclerotomy. — Posterior sclerotomy is performed in the same conditions. It consists in incising the sclerotic and vitreous body in the equatorial region of the globe. The eyeball is turned as far as possible to the nasal side, a Graefe knife is inserted 5 or 6 mm. behind the corneal margin in the horizontal meridian, is advanced about 10 mm. toward the centre of the globe, and then is turned on its axis to allow the escape of fluid. The conjunctiva, having been drawn down slightly with forceps before the incision is made, serves to cover the wound when it resumes its natural position.

X. DISEASES AND INJURIES OF THE LENS.

As disease of the lens affects its transparency, it is usually recognized as some form of opacity, or as a cataract. The lens, even under normal conditions, is never absolutely transparent. Oblique illumination (Fig. 307), with the pupil dilated, will always show a slight grayish reflex, which is more marked in old people, and which may present the appearance of decided opacity notwithstanding the fact that the lens is really normal, as shown by the distinctness of the fundus under ophthalmoscopic examination. It is not always easy to determine where this normal increase of reflex ends and a real cataract begins.

Fig. 307.—Oblique Illumination. (Noyes.)

Senile Cataract.—Senile cataract is the result of a degeneration of the lens that occurs in old age. It is also known as hard cataract in contradistinction to forms in which there is no firm nucleus but which consist chiefly of opaque, soft cortical matter. The principal subjective symptom, and usually the only one, is gradual diminution of vision. For thorough examination the pupil is dilated with cocaine, or homatropine, or a weak solution (gr. ss. or gr. i. to fl. ℥ i.) of atropia. The danger of inducing glaucoma by mydriasis in old people predisposed to it should be remembered, and, if symptoms of it appear, eserine or pilocarpine should be instilled. With mydriasis, oblique illumination shows an increased lens reflex and opaque striations extending from the periphery toward the centre, particularly in the lower nasal quadrant. In the early stage the lens, being enlarged through swelling of the cortical substance, pushes the iris forward, narrowing the anterior chamber and increasing the refraction. The patient becomes myopic, and often finds that he can read without the glasses that he has been using for years. This is popularly called "second sight." Later, the pupil appears grayish, instead of black, even to ordinary inspection, and finally the lens assumes a yellowish tinge, a waxy appearance, and resumes its normal size, or may even shrink. When the whole cortical matter has become opaque and vision is reduced to mere perception of light, the cataract is said to be mature. An uncomplicated cataract never shuts out the light entirely, and when there is no perception of light and the pupil does not react there is some other cause for the blindness, such as optic atrophy or separation of the retina. If the retina and nerve are healthy, and if there is no amblyopia from intracranial causes, the field of vision will be normal, as shown by moving a candle flame or the reflex from the ophthalmoscope in various directions before the eye. The extent to which the cortical matter has become opaque is tested by the shadow cast upon the lens by the edge of the pupil in oblique illumination. If the iris rests upon a lens uniformly opaque throughout its substance, there will be no shadow, for the presence of a shadow shows that the space between the edge of the iris and the opaque portion of the lens is clear.

Hypermature Cataract.—In old hypermature cataract the cortical matter undergoes fatty degeneration, breaks down to a more or less fluid consistence, and has a milky appearance, and there are dense white patches on the capsule.

Morgagnian Cataract.—In Morgagnian cataract the cortical matter is reduced to a fluid condition and is contained in the capsular sac to the bottom of which the hard nucleus falls.

These lenticular changes often take place very slowly, and may not deprive the patient of useful vision for many years. The surgeon, therefore, should not prognosticate early blindness at the first signs of commencing cataract. It is even well, in many cases, to keep the patient ignorant of the condition of his lens.

Occasionally a cataractous lens is of such a dark brownish color that the pupil appears of almost normal blackness, though little or no fundus reflex is seen by the ophthalmoscope (black cataract). This sometimes occurs in connection with choroidal disease and intra-ocular hemorrhage, when the dark color is supposed to be due to the absorption of hæmatin.

Secondary Cataract.—Secondary cataract is a cataract due to impairment of the nutrition of the lens caused by disease in other tissues of the eye, such as chronic choroiditis, separation of the retina, or glaucoma. Myopic eyes are most liable to the choroidal form. The term "secondary cataract" is sometimes applied to obstruction of the pupil by an opaque capsule or by inflammatory exudation resulting from the extraction of the cataract.

Nuclear Cataract.—In nuclear cataract the opacity is entirely or mainly in the nucleus of the lens, which presents a haziness behind the pupil. There are also, in most cases, some spiculæ of opacity in the periphery of the cortex.

Cortical Cataract.—In cortical cataract the opacity is chiefly in the cortex —generally in the form of striæ, spiculæ, or patches, most numerous in the lower nasal quadrant.

Diabetic Cataract.—Diabetic cataract is supposed to be due to interference with the nutrition of the lens by the abstraction of water through exosmosis. (Heubel.) It may have the appearance of ordinary senile cataract, but in younger subjects presents a diffuse, rather whitish opacity. The introduction of a solution of sugar or of salt under the skin of frogs produces cataract, as does also the injection of naphthalin in rabbits.

Posterior Polar Cataract.—Posterior polar cataract is often found in connection with chronic choroiditis, retinitis pigmentosa, or high myopia. There is a thin patch of opacity at the posterior pole of the lens, with striations extending toward the periphery—changes which are best seen with the ophthalmoscopic mirror. The tendency is to ultimate involvement of the whole lens, but the process is usually very slow.

Anterior Polar Cataract (Anterior Central Capsular Cataract).—In this form of cataract there is a small opacity at the anterior pole of the lens just beneath the capsule. It is sometimes congenital, when it may possibly be due to the remains of the pupillary membrane. The usual cause is a perforation of the cornea in early childhood, often in ophthalmia neonatorum. With the escape of the aqueous humor, the lens capsule, in contact with the ulcer, receives a deposit of exudate. When the ulcer heals and the aqueous humor re-accumulates, the lens is forced back to its place, the capsule is torn away from its adhesion to the cornea, and the deposit on its surface interferes with the nutrition of the subcapsular epithelium, causing a proliferation of cells and the formation of a spot of opaque tissue beneath the capsule, usually projecting in a pyramidal form (*pyramidal cataract*). The whole lens may eventually become opaque, but often the condition remains stationary for many years.

Congenital Cataracts.—Congenital cataracts are soft, and usually present a diffuse whitish opacity.

Zonular Cataract.—In zonular cataract an opaque zone surrounds the nucleus, which, as well as the rest of the lens, remains clear. In course of time the whole lens may become opaque, particularly in cases with radiating striæ, but in many cases there is little or no change for years.

Soft Cataract.—Soft cataract is found usually in young subjects, before the nucleus has hardened. The opacity is more diffused than in senile cataract, and has a whitish appearance.

Capsular Cataract.—Capsular cataract appears as patches or streaks of opacity on the capsule. It is often found in hypermature cataracts.

Traumatic Cataract.—This variety of cataract is caused by rupture of the lens capsule, by direct penetration, or by the concussion produced by a blow. When exposed to the action of the aqueous humor, the lens substance swells and becomes opaque. A very small rupture of the capsule may sometimes heal and the local opacity of the lens remain stationary, but usually the whole lens becomes opaque. If an extensive tear of the capsule allows a large portion of the lens to escape, the swelling of the cortical matter is likely to cause glaucoma or iritis, or both. In favorable cases, particularly in young subjects, the lens is gradually absorbed, leaving a pupil which may be entirely clear or may be more or less obstructed by opaque capsule. If iritis ensues, the lens may become involved in inflammatory exudation which prevents absorption, and the cataract may remain permanent.

Dislocation of the Lens.—Dislocation of the lens often occurs from rupture of the suspensory ligament by a blow. It may be either complete or partial. When it is complete the lens passes into the vitreous body or into the anterior chamber; and when the sclerotic is ruptured, it may pass under the conjunctiva. But more frequently the dislocation is partial, the lens swinging backward and forward on the part of the ligament which remains intact, like a shutter on its hinges. The iris, when it loses the support of the lens, vibrates with the movements of the ball (iridodonesis)—a symptom which is always present in dislocation or absence of the lens, unless prevented by iritic adhesions. A totally dislocated lens always becomes opaque, and a partially dislocated one is likely to undergo this change. (Plate XXXV, Fig. 1.) In congenital dislocation the lens in usually displaced upward, and the curve of its lower margin is seen across the pupil with the ophthalmoscope or by oblique illumination. (Plate XXXV, Fig. 4.)

Treatment of Cataract.—No internal medication or external application is of use in causing the disappearance of a cataract, but much may be done in the early stages to retard its progress by maintaining the general health of the patient, improving his nutrition, and keeping the eye at rest. If errors of refraction have existed, or are induced by the lenticular changes, they should be carefully corrected, the glasses should be changed from time to time, if necessary, and only moderate use of the eyes with large print and good light should be allowed. If the eyes are sensitive to light, smoked glasses are useful. A gouty or rheumatic diathesis should receive careful attention. When the opacity is

EXPLANATION OF PLATE XXXV.

Dislocation of Lens and Traumatic Cataract.

Fig. 1.—The clear lens is dislocated into the anterior chamber, and rests upon the anterior surface of the iris. (Oliver.)

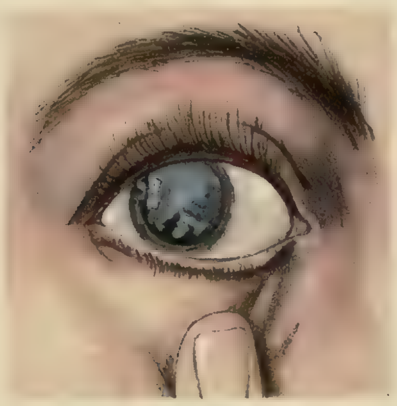
Fig. 2.—Shows shreds of capsule remaining after absorption of traumatic cataract. (Oliver.)

Fig. 3.—Shows rupture of capsule and traumatic cataract. (Oliver.)

Fig. 4.—Congenital dislocation of lens upward and outward, seen by oblique illumination. (Risley, in Transactions of American Ophthalmological Society, 1906.)

I

II



III

GEO H WALKER & CO. BOSTON

IV

Dislocation of Lens and Traumatic Cataract

chiefly nuclear, useful vision may often be preserved for a considerable time by keeping the pupil dilated with a weak solution of atropia (gr. ss. or gr. i. to fl. ℥ i.), applied often enough to maintain mydriasis, but the possibility of inducing glaucoma should not be forgotten. In pyramidal or zonular cataract an iridectomy or sphincterectomy will often give useful vision. In complete cataract the only remedy is removal of the lens.

XI. OPERATIONS FOR CATARACT.

If there is conjunctivitis, it should be relieved by treatment before an operation is performed, care should be taken that the lachrymal passages are in a healthy condition, and the operation should be deferred if they show any tendency to suppuration. If treatment fails to restore them entirely, they may be temporarily closed by passing sutures around the canaliculi. In obstinate cases of dacryocystitis it may be necessary to extirpate the lachrymal sac.

It is generally admitted that, with any antiseptic solution which the delicate tissues of the eye will bear, it is not possible to secure absolute asepsis, and much dependence is placed upon the mechanical removal of germs from the conjunctival sac. The skin about the eye, however, can be thoroughly sterilized. An hour or two before operating, the brow, nose, cheek, and lids are thoroughly washed with castile soap, then with alcohol or ether, and finally with a 1:1,000 solution of bichloride, special care being taken to disinfect the lid margins without irritating the conjunctiva. The conjunctival sac is thoroughly douched with a 1:5,000 bichloride or a saturated boric-acid solution, and the eye is closed and covered with gauze wet with a 1:5,000 bichloride solution and a bandage. Just before the operation, a few drops of a sterilized four-per-cent solution of cocaine are applied three or four times at intervals of five minutes, the conjunctival sac is again flushed with the boric-acid solution, and the roots of the lashes are well scrubbed with absorbent cotton saturated with the same solution. The cutting instruments are rubbed with absorbent cotton wet with alcohol, the others are boiled, and all are placed in a tray in sterile water, ready for use. The

FIG. 303.—Knapp's Discission Needle.

hands of the surgeon and his assistants are, of course, thoroughly sterilized, and the usual care is exercised not to touch anything that has not been made aseptic.

Discission.—Discission is applicable to soft cataracts, usually in patients not more than thirty or thirty-five years of age. The object of the operation is to cause the absorption of the lens by subjecting it to the action of the aqueous humor. The instrument used is a discission-needle (Knapp's knife, Fig. 308, or a Hay's knife, Fig. 309) with a shank that fills the wound to prevent the escape of aqueous humor. The eye is cocainized, and the pupil is dilated with atropia. The needle penetrates the temporal side of the cornea about midway between its margin and centre, and a horizontal incision 3 or 4 mm. long is made through

FIG. 309.—Hay's Knife Needle.

the capsule, and is crossed by a similar vertical incision. It is generally necessary to repeat the operation several times at intervals of two or three weeks, and, if the first operation is well borne, the subsequent discissions may be made more freely. In older patients with a somewhat firmer nucleus a hole is sometimes bored through the lens with the point of the needle. The after-treatment consists in the use of a bandage for a few days, the application of atropia, and frequent flushing of the conjunctival sac with boric-acid solution.

If a quantity of lens matter escapes into the anterior chamber and causes irritation of the iris or symptoms of glaucoma, it should be evacuated. An incision 5 or 6 mm. long is made in the cornea with a keratome, midway between the pupil and the margin of the cornea, and is made to gape by pressing back its lower edge with a spatula or a grooved curette. This is sometimes done at once after free laceration of the capsule, and is then called *linear extraction*—an operation often required in traumatic cataract. Linear extraction has also been performed for the removal of the clear lens in cases of high myopia.

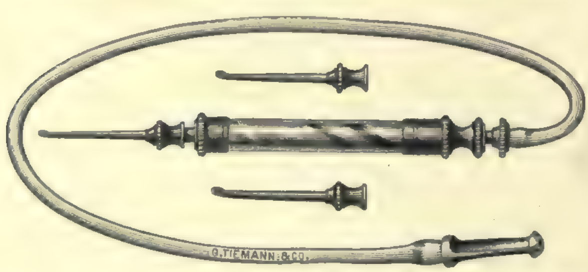


FIG. 310.—Teale's Curette-shaped Cannula for Use in Removing Cataract by Suction.

Teale's Suction Operation. — In this operation a slightly curved curette-shaped cannula, with an opening near its point on the concave side, is used. (Fig. 310.) It is connected to an india-rubber tube with a mouthpiece. The end of the cannula is entered into the anterior chamber through the corneal wound, and passed behind the cortical mass, which is drawn out by suction with the mouth; or a small syringe may be used. The point of the cannula should not be passed beneath or against the iris.

Extraction of hard cataract is either combined with iridectomy, or it is performed without this preliminary operation.

Simple Extraction.—Simple extraction is to be preferred in cases of firm, mature cataract and active iris, without complications, and in patients who can be kept reasonably quiet after the operation. If there is no skilled assistant at hand, the spring speculum is inserted; but, with a competent assistant to control the upper lid with an elevator, this instrument can be more quickly and safely removed in case of accident, such as the escape of vitreous. The patient is directed to breathe through the mouth and to avoid straining, the conjunctiva

FIG. 311.—Graefe Cataract Knife.

is grasped with fixation-forceps just below the cornea, or, if the conjunctiva is too relaxed and distensible to afford a firm hold, the forceps is pressed more deeply into the subconjunctival tissue, and the ball is drawn slightly downward.

The Graefe knife (Fig. 311) is held by the pulps of the thumb, index and middle fingers, and is manipulated with the fingers alone without action of the wrist. (Fig. 312.) It is made to penetrate at the corneo-scleral junction on the temporal side and in the horizontal meridian, to pass across the anterior chamber, and to make the counter-puncture at a corresponding point on the nasal side, and the knife is pushed forward as far as possible. (Fig. 313.) The incision is completed by an upward pressure and a sawing movement of the knife until its edge passes beyond the cornea. A narrow conjunctival flap is thus formed. The blade is held carefully in a plane parallel to the iris throughout the incision, to avoid making an irregular wound which heals less readily than a clean and even one. The conjunctival flap is turned over on to the surface of the cornea, and the cystotome (Fig. 314) is introduced sidewise and with its knee forward, passed down to the lower margin of the lens beneath the margin of the iris, and made to cut the capsule to the upper margin of the pupil. A second incision is made, joining the first below and forming a V-shaped opening which allows the lens to escape while the flap of capsule contracts. If the lens does not come forward, an incision may be made across the top of the V, or other incisions may be made freely lacerating the capsule. Knapp prefers to make a single incision 6 or 7 mm. in length, parallel to the corneal wound, and as near as possible to the upper periphery of the lens (*peripheric capsulotomy*). The cystotome is withdrawn sidewise and with its knee forward to avoid catching in the iris. If the patient can be trusted to look downward, directing the other eye toward his hand, the forceps

FIG. 312.—Method of Holding Graefe Knife. (Landolt.)

may now be laid aside and, while slight pressure is made with the back of the spoon on the upper edge of the wound to make it gape, the finger over the lower lid presses backward against the lower part of the cornea to tilt the lens which engages in the wound. Careful upward pressure of the finger upon the lid is kept up until the lens escapes, when it may be caught in the spoon. This manœuvre is repeated until all loose cortical matter is removed, and the pupil appears black. The edge of the lid should not be brought in contact with the wound.

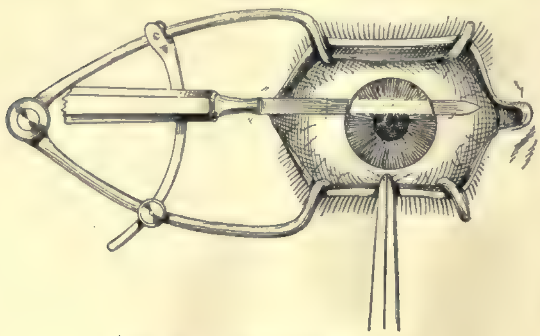


Fig. 313.—Extraction Incision.

If the patient cannot control the eye, the hold of the fixation-forceps is retained, the lens being extruded and cortical matter removed by backward and upward pressure with the back of the spoon.

The conjunctival sac is flushed with warm boric-acid solution, the conjunctival flap is replaced, and the eye is carefully inspected to see that the pupil is clear and the iris in place. A fold of gauze or a small wad of cotton wet with 1:5,000 bichloride solution is placed over the closed lids, and over this is laid enough aseptic absorbent cotton evenly to fill out the orbit. This is held in place by strips of court plaster, and both eyes are lightly bandaged with a gauze roller. An anodyne (chloral and morphia) is administered at night, and the patient should be watched during the first night at least, to see that he does not make any attempt to rise and does not displace the dressings by movements in his sleep. It is better for him to lie absolutely quiet on his back for twenty-four hours. The eye should be inspected the next day to see if the iris is in place. The examination is made in a partially darkened room by means of a candle held by an assistant near the patient's temple, and an oblique light is thrown upon the cornea with a convex lens. If the iris has prolapsed, it should be excised at once. To do this it may be necessary to etherize a nervous patient. If the pupil is round and central, a few drops of a sterilized solution of atropia are instilled into the lower cul-de-sac, the lids are bathed with warm water, and absorbent cotton and the dressings are reapplied. The same is done daily afterward, with the addition of gentle douching with warm boric-acid solution. After the first day the patient may be allowed to turn over upon the unoperated side or to be propped in a bed-rest, but any effort to rise unassisted or any coughing or straining should be avoided. Old and feeble patients, if kept too long upon their backs, are liable to suffer hypostatic congestion of the lungs, and it is often necessary to let them sit up

Fig. 314.—Cystotome.

in bed or in an easy chair. The diet, for several days, should be fluid, or such as does not require actual chewing. The dressings may be removed from the sound eye on the third or fourth day, but they should be applied to the other eye for several days longer. If the operation has been a combined one and the patient is quite comfortable, the dressings may be left undisturbed for forty-eight hours; and then, if the cotton contains no pus, but only a slight stain, the eye need not be opened, but the lower lid is drawn down to allow the tears to escape, the lids are bathed externally, and atropia is dropped into the lower cul-de-sac. Afterward the treatment is the same as that employed after the simple extraction, except perhaps that the confinement may be rather less rigid. A rough test of the vision may be made in ten days or two weeks, but lenses should not be ordered until after the lapse of six or eight weeks. In the mean time simple smoked glasses are used.

Extraction with Iridectomy (Combined Extraction).—This is the safer course to pursue if the cataract is not mature, if the pupil fails to dilate under cocaine, or if the patient is restless or for any reason cannot be kept for several days upon his back. The incision may include a little less than half the circumference of the cornea, and iridectomy is performed as described under that head. Otherwise the steps of the operation are the same as in simple extraction. The iridectomy is a small one, its chief object being to prevent prolapse of the iris by making a free communication between the anterior and posterior chambers. Some surgeons accomplish this by making a buttonhole opening in the upper part of the iris.

A preliminary iridectomy is sometimes performed several weeks before the extraction, particularly in cases which are complicated with posterior synechiæ, or in which there is considerable clear cortical matter remaining. Its advantages are that the only painful part of the operation is performed without complicating the extraction, that there is no iris hemorrhage to interfere with the extraction,

FIG. 315.—Wire Loop.

and that the fresh wound of the cut iris is not exposed to cortical matter left in the anterior chamber. It is probably the safest of all operations for extraction. Its disadvantage is that it subjects the patient to two operations and a longer stay in the hospital. Extraction should not be undertaken until the eye is entirely free from irritation.

Extraction of the Lens in Its Capsule.—This is an old operation revived by Pagenstecher, whose name is frequently associated with it. Pagenstecher, after making a large incision below and farther back than the usual one, performed an iridectomy, and removed the lens in its capsule by passing a spoon-shaped instrument behind it and then withdrawing it. The wire loop (Fig. 315) is now preferred by those who use any traction instrument, but most surgeons make the ordinary upward incision and expel the lens by the same manipulations as those used after capsulotomy. The liability of the capsule to burst during the extraction of the lens, and the great danger of prolapse of the vitreous body, have prevented this method of extraction from becoming general, but it is admitted to be useful in certain cases, such as dislocated cataractous lenses, overripe cataracts with tough capsules, tremulous cataracts with atrophied suspensory ligaments, etc. Recently Major Smith and other surgeons of the British East-Indian Service have performed it successfully in a large number of cases, and are urging its general adoption.

Couching.—In the old operation of couching, a broad needle was passed through the lower part of the cornea to the upper margin of the lens, its flat surface was then applied to the capsule, and, by raising the handle of the instrument, the lens was forced down into the lower anterior part of the vitreous body. In favorable cases, which were few, the lens remained in its new position, the cortex was absorbed, and the nucleus adhered to the ciliary processes. More frequently the capsule was ruptured during the operation, or the lens bobbed up and caused iridochoroiditis, disorganization of the vitreous body, glaucoma, or detachment of the retina. The operation may be considered obsolete, though it has been recommended to resort to it in certain desperate cases, as when the other eye has been lost, after extraction, by reason of intra-ocular hemorrhage.

Artificial Maturation.—Though the chances for a good result are better when the cataract is mature, it is often necessary to operate on an immature cataract, if useful vision is lost, rather than to wait for the completion of a process that may occupy years, or indeed may never be complete. Under these circumstances, an operation to hasten the ripening of the cataract is sometimes performed. After preliminary iridectomy, when the lens comes forward with the escape of aqueous humor, it is subjected to massage by pressing and stroking it through the cocainized cornea, with the back of the shell-spoon or a spatula; or a small spatula is introduced into the anterior chamber and applied directly to the lens. This causes opacity of the cortical matter, and the lens is extracted after the lapse of a few weeks. The same object is sometimes accomplished by incising the capsule with a needle. Some surgeons prefer to extract without this preliminary, particularly in patients more than sixty years of age, when they consider that the lens is hard enough to be removed with comparative safety.

Recently there has been much discussion (Lippincott, McKeown, and others) as to the value of *intra-ocular irrigation in cataract extraction.* Some surgeons wash out the anterior chamber and clean the wound by means of a special syringe or irrigator, the beak of which is inserted just within the lips of the corneal wound. Different forms of irrigators and various solutions have been recommended, but the operation has not been adopted by a majority of ophthalmic surgeons. LaGrange and Aubaret (*Archives d'Ophthalmologie*, February, 1905) urge the importance of carrying out the procedure with a syringe constructed in such a manner as to produce a simultaneous flow and return, in order to avoid undue intra-ocular pressure by the fluid (Fig. 316), and they also advocate the use of a fluid approximating the composition of the aqueous humor, to avoid injury of the tissues by endosmosis or exosmosis. The solution which they use is compounded of water 1,000, sodium chloride 6.89, calcium chloride 0.221 parts. They think that the use of irritating antiseptic solutions, particularly salts of mercury, has prevented the general adoption of the method. Normal salt solution,

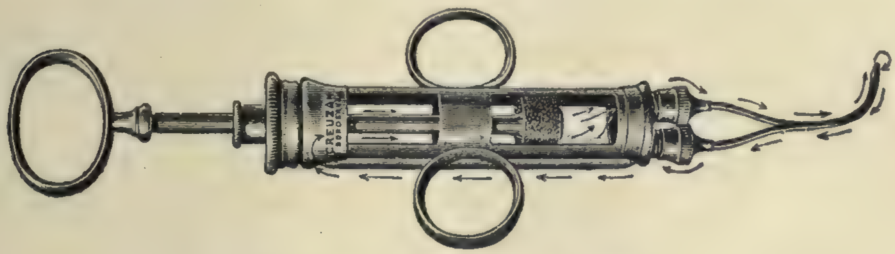


FIG. 316.—Syringe for Anterior Chamber.

carefully sterilized, would probably be safe. The fluid is warmed to a temperature of 37° C. (98° Fahr.) just before it is used.

It is claimed that irrigation is particularly useful in operating on immature cataract, when cortical matter is likely to remain in the anterior chamber after the body of the lens is extracted.

Accidents that May Occur during the Operation.—It has occasionally happened that the surgeon, after making the puncture of the cornea, has discovered that the sharp edge of the knife is turned downward. He has the choice of either withdrawing the knife and postponing the operation, or turning it on its axis to the proper position. The latter is preferable as, if done quickly, it has no injurious effect and is less embarrassing to the surgeon. If the counterpuncture does not fall in the correct position, the point of the knife may be withdrawn and re-introduced without disadvantage. Too small an incision is a serious mistake and should be corrected at once, before one attempts to extrude the lens. The incision may be enlarged with the points of a small pair of scissors or with a blunt-pointed knife. The probe-pointed Weber canaliculus knife will answer. If a fold of the iris falls over the edge of the knife, it is better to go on with the incision, cutting through the iris, and make a clean iridectomy afterward if the iris cannot be released by a forward movement of the knife.

Blood from the cut iris or the conjunctival flap sometimes fills the anterior chamber. The bleeding is usually soon checked by the application of absorbent cotton wet with hot water to the closed lids, with slight pressure. The blood may be evacuated by separating the lips of the wound with a spatula and stroking the cornea with the finger through the lower lid. If it cannot be removed in this way, the capsule is incised, and the clot is extruded with the lens. Any blood that may remain in the anterior chamber is soon absorbed.

Hemorrhage in the Vitreous Body.—Occasionally, when the vision after operation is disappointing, ophthalmoscopic examination shows the presence in the vitreous body of a moderate amount of effused blood, which may be absorbed and not seriously impair the final result, but free bleeding through the pupil during or after the operation is almost necessarily a hopeless sign. It is due to the rupture of weak choroidal vessels, suddenly deprived of the support of intra-ocular pressure, and in some cases not only the lens, but also the vitreous body, has been forced out, their places having been taken by a blood-clot. When intra-ocular hemorrhage occurs subsequently to the operation, it is announced by sudden severe pain, and when the dressings are removed they are found soaked with blood. Extensive intra-ocular hemorrhage during or after extraction is necessarily fatal to vision, and may be followed by shrinking of the eyeball or by panophthalmitis, necessitating enucleation. Iced applications or compress bandages are used for checking the bleeding.

Prolapse of the Vitreous Body.—This may occur immediately after the corneal section is made, during the delivery of the lens or afterward. In the first case a weak suspensory ligament gives way under the pressure caused by spasm of the external muscles in a nervous patient, and cannot be prevented by the most skilful operator. The vitreous body is usually fluid. Escape of vitreous substance with the lens may be due to excessive pressure with the finger or spoon, but is often unavoidable if the suspensory ligament is weak and the vitreous substance in a fluid state. After the lens has been delivered, the vitreous substance may be forced out by too strenuous and persistent efforts to clear the anterior chamber of cortical remains or by straining on the part of the patient. The only preventives are calming the patient as much as possible, directing him to keep his mouth open in order to diminish the act of straining, and exercising great care and delicacy in manipulation. Only very gentle pressure can be used to extrude the lens in such cases, and if the vitreous substance continues to present itself at the opening, it is better to omit pressure altogether and withdraw the lens with the wire loop (Fig. 315). Loss of vitreous substance is a very disturbing accident, but, if the amount lost is slight, it may not seriously affect the result. Even after a very considerable loss, as much as one-third, the collapsed ball may refill and the case do well. If, after gentle pressure with absorbent cotton has been applied over the closed lids for a few minutes, the ball is still collapsed, it has been recommended to fill it with warm sterile normal salt solution and unite the edges of the wound with a fine suture. The Kalt suture, which requires a specially fine needle, includes only the superficial layers of the cornea, not penetrating the whole thickness of the membrane. If the patient is very nervous and unmanageable, or if a similar accident has happened in operating on the other eye, it is safer to administer an anæsthetic. The dressing should be carefully applied, and not removed for forty-eight hours.

If a rigid pupil obstructs the delivery of the lens it may be drawn over the edge of the lens with a fine spatula, or an iridectomy may be performed. It is safer, however, to perform the combined operation in the first place if the pupil does not dilate under cocaine.

Accidents that May Occur after the Operation.—Suppuration of the corneal wound, formerly quite common, is rare since the introduction of aseptic measures. Infection may be caused by conjunctivitis or blepharitis or lachrymal discharge, or may be introduced during the operation or subsequent dressings, or may be endogenous, and is most likely to occur in aged or badly nourished patients with weak resistance. It usually appears on the second or third day, but sometimes later. The patient complains of a burning sensation, and there is profuse lachrymation. The conjunctiva is inflamed and perhaps chemotic, the lids are puffy, the cornea is hazy, and a whitish line of infiltration is seen along the margin of the wound. In favorable cases the symptoms may subside in a few days, but, if the infection is more severe or the patient less resistant, the edges of the wound slough and the whole cornea becomes more or less opaque. In some cases a "ring abscess" forms around the corneal margin, the cornea is destroyed, the iris prolapses, and the suppuration extends to the intra-ocular tissues (panophthalmitis). In the commencement, disinfectant washes and hot stupes, frequently repeated, are used. When a slough forms, the process may sometimes be checked by applying the actual cautery and afterward cleaning the wound daily with hydrogen dioxide on absorbent cotton twisted about the end of a small stick or probe. The eye is to be frequently douched with boric-acid solution, and the hot stupes should be continued. Tonics and stimulants are generally required. Knapp reopens the wound daily with a spatula to drain the anterior chamber. Such cases are desperate, but there may be a chance to preserve some useful vision, or at least the shape of the ball.

Synechiæ.—Synechiæ, shown by irregularity of the margin of the pupil, are nearly always noticed and may be due to simple adhesion of raw surfaces without actual inflammation. A mild iritis, however, with adhesion of the iris to shreds of capsule, is common even in favorable cases. In the more severe forms it is recognized by pain, particularly at night, circumcorneal injection, and discoloration of the iris. It is usually of plastic form, and may close the pupil with adhesions to the capsule and exudations. Iridocyclitis may be considered an aggravated form of simple iritis, and has the same symptoms but in more intense form and with the addition of tenderness on pressure in the ciliary region. The inflammation sometimes extends to the choroid and ends in blindness with disorganization, softening, and shrinking of the eyeball. Spongy or gelatinous iritis has been met with after extraction. (Knapp.) Generally the exudation is absorbed rather rapidly, and such cases may terminate favorably.

Iritis is more likely to occur in gouty, rheumatic, syphilitic, or glycosuric subjects. The treatment is discussed under Iritis. Suppurative iritis is likely to end in panophthalmitis. The iris is discolored, the cornea is more or less hazy, the aqueous humor is cloudy, and pus collects in the anterior chamber. Not much is to be hoped for from treatment. Hot stupes and anodynes give relief. A free incision of the cornea may be required to evacuate pus, and the question of enucleation or exenteration may arise.

Infection may also first show itself in the vitreous body, when a yellowish reflex is seen in the pupil.

Striated Keratitis.—Striated keratitis is not infrequent. It consists of stripes of opacity in the posterior layers of the cornea radiating from the region of the wound. It is most likely to occur when, on account of an unusually large lens or too small an incision, the lens has been delivered with difficulty. It has been thought by some authorities to be due to wrinkling of the deep layers of the corneal flap; it nearly always disappears without special treatment.

Delayed Union of the Wound.—In a few cases the healing of the wound is delayed. Instead of finding the wound closed and the anterior chamber reformed at the end of the first, second, or third day, as is usual in favorable cases, the surgeon may be disappointed to note that the wound is still open in a part or throughout the whole of its extent and the anterior chamber shallow or empty. Cases have been reported in which the wound remained open for three or four weeks, but in which the final result was good. ("Delayed Union after Cataract Extraction," Harlan, Trans. Am. Oph. Soc., 1898.) The local causes for delayed union that have been suggested are an irregular or ragged incision, the presence of bits of capsule, lens débris, shreds of the vitreous body or of the conjunctiva in the wound, hernia of the iris, and entropion. It has occurred, however, in cases in which none of these causes existed, and in these cases it was thought that it might be due to failure of reparative power on account of the general condition of the patient, or to excessive secretion of the aqueous humor. The constant outflow of aqueous humor tends to prevent infection, and these cases generally do well in the end under the continued use of the compress, boric-acid douche, and atropia. If there is anything between the lips of the wound it should be removed by passing the end of a small spatula along the incision. A prolapsed iris should be excised. In some cases in which the operation had been a simple one, iridectomy has been followed by prompt closure of the corneal wound. Stimulating the edge of the wound with the mitigated stick of nitrate of silver has been found useful. If the lips of the wound appear necrotic, they should be lightly touched with the actual cautery. If prolonged bandaging causes inversion of the lids or conjunctivitis, the bandage should be discontinued or used only at night. Hot stupes may be of use, and stimulants and tonics and nourishing diet are required.

Cystoid Cicatrix.—Cystoid cicatrix occurs in cases in which there is not direct union, but in which the wound is filled in with new tissue which yields to the intraocular pressure and bulges. The iris is often involved in the cicatrix. The visual result may be fair, generally with the correction of a high degree of astigmatism. When the iris is included, there is danger of irido-cyclitis, and it has been recommended (Knapp, Berry) to excise the staphyloma and apply the actual cautery.

Filtration Chemosis. (Knapp.)—This condition is due to a leak in the wound and escape of aqueous humor beneath the conjunctiva, causing a glossy œdema which tends to gravitate toward the lowest part of the conjunctiva. Except as a sign that the wound is not entirely closed, it has little or no significance, and disappears when the leakage ceases.

In a few cases sympathetic ophthalmia of the eye not operated upon has been induced by irido-cyclitis of the one upon which the operation was performed, and as a result it has been found necessary to enucleate the latter.

Mental Disorders.—Delirium or even a well-developed attack of mania or dementia occasionally occurs after the operation, usually in nervous or aged patients. It is attributed to anxiety, the abrupt change in the mode of life and surroundings, the complete and prolonged darkness with both eyes bandaged, and the confinement to bed, and perhaps sometimes to the too free use of atropia. When symptoms of it are noticed, the eye not operated upon should be left uncovered and the patient be allowed to sit up with a bed-rest or in an easy chair. Bromides and sometimes morphia and chloral are useful.

After-cataract.—As the term secondary cataract is applied to opacity of the lens due to disease in other tissues of the eye, after-cataract is a better term to employ for obstruction of the pupil by opaque capsule, or by a membrane composed of capsule, adherent and contracted iris, and inflammatory exudation. A wrinkled capsule, even with very little opacity, may considerably impair vision by diffusion of the light passing through it. If the capsule is thin and delicate and likely to retract when excised, an opening is made through it with a discission-needle (Fig. 307), or a Hay's knife (Fig. 308), with a shank so constructed that it will fill the wound and prevent escape of aqueous humor. The needle is entered near the periphery of the cornea, and two incisions are made through the capsule in the form of a cross + or a V. If the capsule is too tough or too movable to be opened in this way, two needles may be inserted from opposite sides of the cornea and made to puncture the capsule at the same point and tear it by separating their points. A dense, tough, adherent capsule that cannot be cut without dragging dangerously upon the periphery of the iris may be cut with the Wecker scissors (Fig. 303), but is sometimes extracted with the iris forceps through an incision in the cornea made with a keratome.

In cases of complete occlusion by a membrane formed of iris and capsule, an iridotomy, or iridocapsulotomy, is required. (See Iridotomy.)

A partially dislocated lens, if it remains clear or if fair vision can be secured by a glass, may be let alone. A completely dislocated lens should be extracted. If it is found in the anterior chamber, it may be held there by contracting the pupil with eserine, or may be prevented from escaping into the vitreous body by passing a needle behind it, while the incision for extraction is made. If it is in the vitreous body, extraction will be more difficult and may be impossible. It is withdrawn by passing the wire loop behind it. (Fig. 314.)

XII. DISEASES OF THE MUSCLES THAT CONTROL THE MOVEMENTS OF THE EYEBALL.

Strabismus or Squint.—Strabismus is a deviation of one eye from the fixing object—the object looked at. The angle formed by the axes of vision of the two eyes is called the angle of deviation. This angle is measured by means of the perimeter. The squinting eye is placed in the centre of the arc, the other eye is directed to a distant object directly in front of it, and the direction of the axis of the squinting eye is noted on the arc, along which a candle is moved until its image falls upon the centre of the cornea.

Paralytic Strabismus.—Strabismus is paralytic or concomitant. In paralytic squint the angle of deviation varies with the position of the object looked at, always increasing in the direction of the paralyzed muscle. If the sound eye is screened and fixation is attempted by the squinting eye, the secondary deviation, the deviation of the sound eye behind the screen, is greater than the primary deviation of the squinting eye. In paralytic squint there is nearly always diplopia, in concomitant scarcely ever. When the object is held in a position that does not require the use of the paralyzed muscle the diplopia disappears.

Non-Paralytic Strabismus.—In non-paralytic or concomitant strabismus the angle of deviation remains constant in all positions of the object fixed, and, if the fixing eye is screened, its secondary deviation is the same in degree as the primary deviation of the squinting eye.

Intermittent and Alternating Strabismus.—Intermittent strabismus occurs only occasionally, particularly when the eyes are directed to a near object. In alternating squint the vision of the two eyes is about the same, and when one is screened the other will continue to fix when the screen is removed. Sometimes the patient uses either eye at will.

Paralytic Strabismus.—The causes of paralytic strabismus are as numerous as those of paralysis elsewhere. The most frequent cause is syphilis. Occasional cases are due to rheumatism; others result from small cerebral hemorrhages or from some one of the various forms of intracranial disease.

Concomitant Convergent Strabismus.—The causes assigned for concomitant strabismus are a defective fusion faculty, a high degree of difference in the refraction of the two eyes (*anisometropia*), errors of refraction, and a weakness or faulty attachment of one or more of the muscles. By far the most common exciting cause, particularly of convergent strabismus, is an error of refraction. A large proportion of the cases of convergent strabismus (according to Wecker, eighty-five per cent) occur in connection with hypermetropia. The hypermetropic eye requires an excessive use of the accommodation, which is closely associated with convergence, and excess of convergence results.

Divergent Strabismus.—Divergent strabismus occurs more frequently in myopic eyes, in which a part of the accommodation must be suppressed on account of the closeness of the far point, and the eyes are unable to maintain the excess of convergence, in proportion to accommodation, required. There has been much discussion as to whether the amblyopia usually found in the strabismic eye is a cause or a result of the strabismus, and the early age at which the strabismus usually commences makes it a difficult question to decide. This amblyopia is thought to be due to the habitual suppression of the image in the squinting eye (*amblyopia ex anopsia*), and the reason we meet with it almost constantly in concomitant squint, and not at all in the paralytic form, may be that in the former the image falls constantly on the same part of the retina, while in the latter it changes its position with every movement of the eyes.

Treatment of the Different Forms of Strabismus.—The treatment of paralytic squint depends upon the cause of the paralysis. If this is syphilis, much may be accomplished by the use of mercury and the iodides. In rheumatic cases the salicylates are called for. Later, the administration of strychnia and the application of galvanism to the paralyzed muscle are often useful. Operative interference should not be considered until it is reasonably certain that the condition is permanent. Even then, the danger of increasing the annoyance from diplopia by bringing the image nearer to the macula should not be forgotten. Some indication of the probable effect of an operation may be obtained by seizing the cocainized conjunctiva with forceps and drawing the eye into position.

In concomitant strabismus the first step in treatment should be the correction of the refraction. In the early stage this alone will often restore the parallelism of the eyes; in intermittent cases it will nearly always do so. If the extreme youth of the patient makes the wearing of glasses impracticable, it is a good plan to compel the use of the squinting eye by keeping the other under the effect of atropia, with a view to preventing amblyopia. If the refractive defect is of high degree, however, children three years of age or less can often be induced to wear glasses, particularly by atropinizing the fixing eye.

Operative Measures.—The question of operation arises if there is no improvement when the glasses have been worn for several months. The operations for strabismus are tenotomy of the contracted muscle and advancement of the opposing one. In the case of young children ether is required, but the operation is rendered almost painless by cocaine. Adrenalin chloride, 1–3,000, will make it nearly bloodless.

In *tenotomy* the tendon of the muscle is cut at its attachment. The position of this attachment is, approximately, 5 mm. from the border of the cornea for the internal rectus, 6 mm. for the inferior, 7 mm. for the external, and 8 mm. for the superior. In tenotomizing the internal or external rectus, a horizontal fold of the conjunctiva is grasped by the fixation-forceps, in front of the insertion of the tendon, and a vertical incision 6 or 7 mm. long is made in it with the probe-pointed scissors of Stevens. (Fig. 317.) The capsule of Tenon is opened with the points of the scissors below the margin of the tendon, and the strabismus-hook is entered with its tip downward, which is then turned up, kept close against the sclerotic, and made to emerge above the upper edge of the tendon. The conjunctiva is pushed aside with the closed points of the scissors until it clears the hook, and the tendon, slightly raised from the ball by traction on the hook, is divided between the hook and the sclerotic by several cuts of the scissors. The tip of the hook is then passed up and down to see that no fibres of the tendon remain uncut. The hook should now pass freely to the margin of the cornea. The connections of the muscle sheath with the capsule of Tenon should not be much disturbed, or there will be danger of an excessive effect, either at once or some time later. The effect of a free division of the internal tendon is usually a change in the direction of the axis of vision amounting to about ten or fifteen degrees. Some operators grasp the tendon with the fixation-forceps instead of using the hook; and others (Snellen, Stevens) make an incision 2 or 3 mm. in length through the conjunctiva over the insertion of the tendon, and a small buttonhole opening in the middle of the tendon, through which a delicate hook is passed, and the tendon is then divided subconjunctivally upward and downward. In a high degree of strabismus it is better to operate upon both eyes than to separate the attachment of the sheath of the muscle to the capsule too freely in one; or, better still, one may combine advancement with tenotomy. As the effect of a tenotomy of the internal rectus tends to increase more or less in time, a slight degree of convergence should remain after the operation. After tenotomy of the external rectus, the tendency is rather for the effect to decrease, and the section here may therefore be made more freely. According to von Graefe, a free tenotomy of the external rectus changes the direction of the axis of vision about sixteen degrees.

Fig. 317.—Stevens Tenotomy Scissors.

While the object of tenotomy is to weaken the effect of a muscle by giving it an attachment farther back on the globe, that of the procedure known as "advancement" is to increase its effect by moving its attachment farther forward. Many authorities (particularly Landolt) urge that it is more rational to increase the power of a weak muscle than to weaken its antagonist, and have practically abandoned tenotomy as an operation for squint, except in cases requiring both. The disfiguring sinking of the caruncle and the exophthalmos which sometimes follow tenotomy are also avoided. A multitude of operations and modifications of operations have been proposed. The following description of advancement is from Worth: "The surgeon grasps the conjunctiva with the toothed forceps, while with the scissors (blunt-pointed) he makes a straight vertical incision

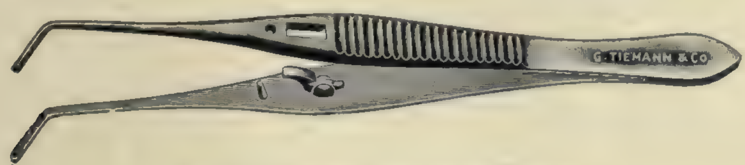


Fig. 318.—Prince's Advancement Forceps.

through it about half an inch long. The middle of the incision is close to the corneal margin. A similar incision is made through the capsule of Tenon. The conjunctiva and capsule then retract, or, if necessary, they are pushed back so as to expose the insertion of the tendon. The smooth blade of a Prince's advancement-forceps (Fig. 318) is now passed under the tendon, after the manner of a tenotomy hook, the toothed blade being superficial to the conjunctiva. The forceps is now closed, so that tendon, capsule of Tenon, and conjunctiva are all firmly clasped together with their relations unchanged except for the retraction of the membranes. The tendon, and a few little fibrous bands beneath the tendon, are now divided with scissors at their insertion into the sclerotic. The Prince's forceps, holding the tendon, capsule, and conjunctiva, can now easily be lifted up so as to afford a good view of the under-side of the muscle. One of the needles is then passed inward at *A* (Fig. 319), through the conjunctiva, capsule, and muscle, and brought out at the upper side of the muscle. It is then again

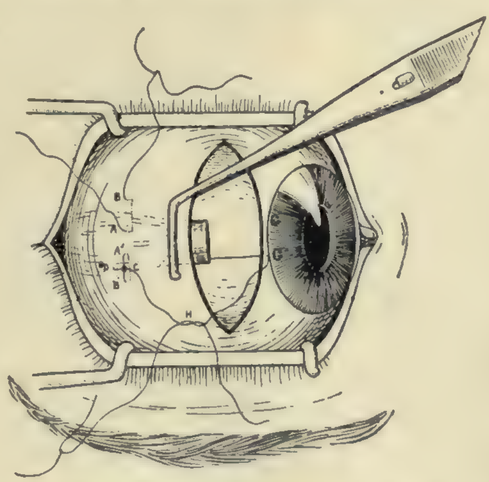


Fig. 319.—Advancement Operation. (Worth.) The patient is lying upon his back. For explanation of details consult the text.

passed through the muscle and conjunctiva, and brought out at *B*. The bight of the thread thus encloses about the upper fourth of the muscle, together with its tendinous expansions and capsule and conjunctiva. The other needle is similarly inserted at A', passed through the conjunctiva, capsule, and muscle, and brought out at the under side of the muscle. It is then entered again at the under side of the muscle, and brought out through the conjunctiva at B', the bight of this suture thus enclosing the lower fourth of the width of the muscle, etc. The object of inserting both sutures before proceeding further with either is that they may be symmetrically placed. The ends of the threads from B and B' are then knotted tightly at C and C'. The ends bearing the needle are then entered at D and D' and passed through the conjunctiva, capsule, and muscle, and carried beneath the lower blade of the Prince's forceps nearly to the corneal margin. The needles are then passed through the tough circumcorneal fibrous tissue (superficial layers of the sclerotic) and brought out at G and G'. The two ends of the threads are then temporarily tied loosely with a single hitch at H and H'. The anterior part of the muscle and capsule and conjunctiva are then removed by cutting them through with scissors behind, where they are grasped by the Prince's forceps. The gap is then closed by tightening and securely tying each suture at H H', so that the eyeball is rotated in its correct position, and the anterior end of the muscle is brought nearly to the corneal margin at G G'. The longitudinal position, on the muscle, of the loops A B C and A' B' C' varies according to the degree of rotation required." Both eyes are bandaged for three or four days, and afterward the operated one only for a few days longer. The conjunctival sac is flushed daily with boric-acid solution. The sutures are removed on the eighth day.

XIII. GLAUCOMA.

Glaucoma is a term given to a complex group of symptoms which can be referred to an increased intra-ocular tension, a hardness of the eyeball, and is thought to be due to an obstruction to the normal outflow of fluids from the eye, or to an increase in their secretion. Anything that closes the angle of the anterior chamber, the filtration-angle, and the canal of Schlemm may cause it. If not checked by proper treatment, the condition leads certainly to loss of sight. Every surgeon should be able to detect it, and not allow his patient to drift into hopeless blindness while being treated for "neuralgia," as has so often happened.

Glaucoma is primary, occurring without previous disease, or secondary to some other affection of the eye, such as iritis, cyclitis, traumatic cataract, or dislocation of the lens. Exclusion of the pupil with iris bombé is a frequent cause. An attack is often induced by the use of a mydriatic, which obstructs the filtration-angle by crowding the base of the iris into it.

Symptoms.—The first symptoms of acute glaucoma are usually intermittent attacks of dimness of vision, the appearance of rainbow halos about lights, such as street-lamps, with more or less pain referred to the eyeball and orbit. Later, these attacks of pain and dimness of vision occur more frequently and are more severe, and the pain, which extends to the face and sometimes to the whole side of the head, may be intense and is not relieved by any drug, except such as diminish intra-ocular tension. There are sometimes vomiting and great depression. The pupil is dilated, and the sensation of the cornea, tested with a little roll of cotton twisted to a point, is diminished or lost. In the later stages the cornea becomes dim and hazy. Pressure with the end of the finger on the equator of the ball, through the lid, shows that it is harder as compared with the unaffected eye or with a healthy one of a person of the same age. This symptom, when in moderate degree, may be difficult to elicit, but is often strikingly evident. It is rather indefinitely recorded as T + 1 when the hardness is just noticeable, T + 2 when it is more decided, and T + 3 when the ball is stony hard. The anterior chamber is shallow, the deep subconjunctival vessels are injected, and there is sometimes a congested pericorneal zone. The field of vision is contracted, particularly on the nasal side. All of these symptoms, which are explained by increased intra-ocular tension, may not be found in every case, but any of them in association with a dilated pupil should excite suspicion. Sometimes they appear suddenly and with violence (*Glaucoma fulminans*). The ophthalmoscopic appearances are cupping of the disc and pulsation of the retinal arteries. The former may not be present in the early stages.

In chronic glaucoma the chief subjective symptoms are progressive diminution of vision and inability to use the eyes with comfort. There may be no pain and only slight discomfort. There is an increase of hypermetropia or presbyopia, and stronger glasses are required for reading. The increased tension may be difficult to determine, and the pupil may be but slightly or not at all dilated. The diagnosis depends mainly on the cupping of the disc and the contraction of the field of vision. The progress of the disease is slow, and may last for years.

Treatment.—The treatment of acute glaucoma is a broad and peripheral iridectomy (see page 619), and the sooner it is performed the better the result is likely to be. In the early stages it can usually be depended on to check the progress of the disease, and in many cases will restore the vision to nearly normal. If there are good reasons for delay, an attempt to contract the pupil with a myotic (eserine gr. ss. to gr. iv.–fl. ℥ i., applied three or four times a day) may be made, and in a few cases this may permanently cut short an attack, but usually this measure must be considered palliative rather than curative.

Hemorrhagic glaucoma occurs in connection with hemorrhages in the retina or the vitreous body. In these cases iridectomy is likely to be followed by bleeding from the choroidal vessels, and is to be avoided. Sclerotomy (see page 623) may be of use, but the prognosis is unfavorable.

In chronic glaucoma the results of operation are not so satisfactory, but it is generally considered that iridectomy affords the best chance of at least delaying the progress of the disease. It is not, however, without its danger, as it is sometimes followed by impairment of the central vision, particularly when the contraction of the visual field has reached nearly to the fixation-point. It cannot be urged with the same confidence as in the acute form of the disease. If operation is declined, something may be accomplished by the use of a myotic. Pilocarpine (gr. iv. to fl. ℥ i.) is less irritating than eserine, or a weak solution of eserine (gr. ¼ to gr. ss.–fl. ℥ i.) may be used.

XIV. INTRA-OCULAR TUMORS AND FOREIGN BODIES IN THE EYEBALL.

The most common intra-ocular tumors are sarcoma in adults, and glioma or glio-sarcoma in young children.

Sarcoma.—Sarcoma generally originates in the choroid. Its earliest symptoms are usually loss of vision in a part of the field, due to separation of the retina, and increased intra-ocular tension. Later, the eye becomes disorganized, and the tension may be diminished. If allowed to progress, the new-growth breaks through the sclerotic, infects the orbital tissue, and ends in the death of the patient by extension to the brain, exhaustion, or metastasis to other parts.

Glioma.—Glioma is a disease of early childhood, and does not often occur after twelve years of age. It is sometimes congenital. Attention is first called to it by blindness of the eye and a peculiar yellowish reflex from the pupil. The eye is hard in the early stages, but, if irido-cyclitis has been set up, it may become soft by disorganization of the ball. The growth of a glioma is more rapid than that of sarcoma, and it has a tendency to extend through the optic nerve. Like sarcoma, it may penetrate the sclerotic and infect the orbital tissues, and end in death by extension to the brain, by exhaustion, or by metastasis.

A collection of pus in the vitreous body in purulent choroiditis often closely resembles glioma, and is called *pseudo-glioma*. It is distinguished from glioma chiefly by a history of inflammation and by diminished tension. In doubtful cases it is better to treat it as glioma, as the eye is useless.

Treatment of Malignant Intra-ocular Tumors.—The only effective treatment of these growths is early removal of the ball. If this is accomplished while the tumor is small, there is a chance of permanent cure; and, even if the growth fills the ball, if it has not ruptured the sclerotic, the case is not absolutely hopeless. If the orbit is involved in the disease its contents should be entirely removed, including the periosteum; but even then recurrence is almost certain.

Foreign Bodies in the Eyeball.—Foreign bodies in the eyeball, if not aseptic, cause infective inflammation, which not only destroys the injured eye, but endangers the other from sympathetic ophthalmia. If aseptic, they may act as mechanical or chemical irritants. A penetrating wound in the cornea or sclerotic should always excite suspicion of the entrance of a foreign body, and if the iris or lens is wounded this suspicion becomes almost a certainty, unless the wound has been made by some comparatively large instrument that has surely been withdrawn. If the media are clear, the foreign body may be detected with the ophthalmoscope. If it cannot, it should be searched for and, as nearly as possible located, by x-ray examination. If the object is of iron, it can often be removed with the electro-magnet. The large, powerful fixed magnet of Haab is used for drawing the foreign body out through the wound of entrance, which may be reopened or enlarged, if necessary; or for drawing it around the margin of the lens into the anterior chamber, whence it is removed through an incision in the cornea. Portable magnets (one of the best being Sweet's) have probe-points which are introduced through an incision in the sclerotic in the position of the particle of iron, as determined by the ophthalmoscope or by an x-ray examination. These points are, of course, carefully sterilized before they are inserted. The wound in the sclerotic is closed by a stitch, and iced cloths are applied. The conjunctiva is drawn away from the place where the incision is made, and, when it is allowed to fall back into place, the wound will be found to lie wholly covered by conjunctiva.

For the removal of a non-magnetizable body the forceps are introduced closed, and opened in the vitreous body or in the anterior chamber. If lodged in the iris, the foreign body may be removed by iridectomy. If the foreign body cannot be removed, it will usually be necessary to enucleate the eyeball. A small aseptic body occasionally becomes encysted in the choroid or lodged in the sclerotic, and does little or no damage; but this is an exception, and such an eye should be kept under observation.

XV. OPERATIONS UPON THE EYEBALL.

Enucleation of the Eyeball.—This operation is required for extensive wounds,—particularly if they involve the ciliary region,—for the presence of a foreign body or intra-ocular growth, for painful absolute glaucoma, for sympathetic irritation resulting from an irritable eye in which sight has been lost by injury or disease, or for the relief of pain and danger of sympathetic ophthalmia in an eye destroyed by panophthalmitis or chronic cyclitis. After insertion of the spring speculum, a fold of conjunctiva is taken up near the temporal margin of the cornea in the conjunctival forceps, and incised with scissors. One blade of a small pair of blunt, curved scissors is passed into this opening, and the conjunctiva is cut all around the cornea and is dissected up toward the equator of the ball. Then each of the straight muscles is taken up in turn on the strabismus-hook and cut close at its insertion, except that a stump of the external rectus is left to afford a hold for the forceps. This is seized with the forceps, and the eyeball is turned strongly toward the nose, while the large, curved, blunt enucleation-scissors are passed along the sclerotic, closed, and used as a probe with which to feel for the optic nerve. When this has been found, the scissors are slightly withdrawn, opened widely, and pushed forward, and the nerve is severed with a single cut. The ball is then forced out between the lids by drawing it forward and pressing back the speculum, and the oblique muscles and any other attachments are cut close to the sclerotic. In the case of intra-ocular growths the nerve should be severed as far back from the ball as possible, by pressing backward the points of the scissors and drawing the ball forward. If the ball is soft, care is required not to cut the sclerotic, a fold of which may be caught in the scissors. Inflammatory adhesions of the conjunctiva and the capsule of Tenon may require tedious dissection as the muscles are cut. It is not necessary to stitch the conjunctiva. Hemorrhage is checked by inserting pledgets of absorbent cotton wet with very hot water, the orbit is douched with bichloride solution and dusted with iodoform, a compress of cotton is applied over the closed lids, and a bandage is applied. The orbital cavity is washed daily with an antiseptic solution, and the dressing is reapplied.

Some surgeons, to give a better movement to the ball, pass a thread through each rectus muscle, as it is cut, and through the overlying conjunctiva, and knot it, and, after the ball is removed, tie together the ends of the rectus externus and internus and of the rectus superior and inferior. An artificial eye can be inserted as soon as the wound is healed and the irritation has subsided,—*i.e.*, usually at the end of two weeks or a month.

Evisceration of the Eyeball.—This operation is sometimes performed instead of enucleation, with a view to obtaining a more movable stump for the artificial eye. The sclerotic is incised, just beyond the corneal margin, with a Graefe or Beer cataract knife, to admit the small curved scissors with which the incision is completed around the whole circumference of the cornea; and the contents of the ball are removed with forceps, scoop, and pledgets of absorbent cotton twisted on the end of a stick or probe. After disinfection of the interior, the edges of the sclerotic are brought together with stitches, the projecting angles of the wound are cut off, and the conjunctival wound is united.

The Mules Operation.—In the Mules operation a hollow glass ball is inserted in place of the vitreous body after the evisceration. A slit is made in the sclerotic at each side of the opening, to admit the ball; and, after the angles of the slit are trimmed to make a smooth cicatrix, the wound is closed by bringing the edges of the sclerotic together horizontally with catgut sutures. The conjunctiva is sutured in a vertical direction with silk threads, which are removed on the third day. The insertion of the glass ball is facilitated by an instrument devised for the purpose. (Fig. 320.) Gold and paraffin spheres have been used.

FIG. 320.—Instrument for Inserting Glass Ball in Mules' Operation.

The glass ball is also sometimes inserted in the capsule of Tenon after enucleation, and the ends of the straight muscles are sutured over it with the conjunctiva. These operations give the artificial eye free movement and a more natural appearance, by avoiding the sinking of the skin over the upper lid which is seen after simple enucleation. They are not applicable to cases of intra-ocular growths, or to those in which there has been a high degree of suppurative inflammation.

XVI. DISEASES AND INJURIES OF THE ORBIT.

Orbital Cellulitis.—Idiopathic cellulitis of the orbit is extremely rare. The most frequent causes are traumatism and extension of inflammation from the eye or from the accessory cavities of the nose, particularly the frontal and ethmoidal sinuses. Phlegmonous erysipelas of the face frequently extends to the orbital tissues. Orbital cellulitis also occurs as a metastatic inflammation in puerperal fever, phlebitis, carbuncle, etc. It may have its origin in suppurative phlebitis of the ophthalmic vein, caused by abscesses of the lids or lips, by operations about the face, or by the extraction of teeth. Cases occurring in diphtheria have been reported.

The most striking symptom of orbital cellulitis is the exophthalmos due to swelling of the orbital tissue. In the early stage, diplopia resulting from slight displacement of the eyeball may be noticed before the exophthalmos excites attention. Later, the protrusion of the ball may be so great that the lids can no longer cover it. When an abscess is evacuated spontaneously, the pus escapes through the skin of the lids near the orbital margin or through the sulcus of the conjunctiva. In the latter case the disease may be mistaken for purulent conjunctivitis. Pain is severe in acute cases, but occasionally the disease assumes a chronic form which is almost painless and may last for months. A few cases end by resolution, but suppuration is the rule. The diagnosis in chronic cases is not always easy, as the prominent symptom, exophthalmos, is met with in periostitis and in new-growths in the orbit. The difficulty that may occur in diagnosis is shown by the well-known case of Marshal Radetzky, who had been suffering for several months with pronounced exophthalmos. Professor Jaeger, who was sent to Milan by the Austrian emperor to examine him, reported that the patient, who fortunately refused operation, was affected with cancer of the orbital tissue which would probably soon end his life. Soon afterward, under homœopathic treatment, there was a spontaneous discharge of pus and the eye returned to its normal position.

It is only in rare chronic cases that such a mistake is likely to happen. A tumor, unless situated in the muscular funnel (as in tumor of the optic nerve), does not cause the eye to protrude directly forward, but upward or downward or to one side, according to its location, and it can often be felt by pressing the finger deeply into the orbit above the eyeball.

A tender spot on the orbital wall can sometimes be felt in the same way in case of periostitis, which also gives an oblique direction to the exophthalmos.

Exophthalmos also frequently results from postorbital venous obstruction, without disease of the orbital tissue, as in thromboses, aneurism, or new-growths in the cavernous sinus. Cases in which some disease of the blood-vessels is the cause of the exophthalmos are distinguished from cases of orbital cellulitis by the fact that the eyeball can be temporarily replaced by moderate pressure, particularly when the carotid is compressed.

Orbital cellulitis may be dangerous, not only to sight, but to life, though the prognosis is usually favorable. The optic nerve may be paralyzed by stretching and pressure, the cornea may slough from exposure, or the inflammation may extend to the intra-ocular tissues. Life is threatened by extension of inflammation to the brain, or by thrombosis of the intracranial sinuses.

Treatment.—In the early stage of sthenic cases of orbital cellulitis leeches applied to the temple and iced cloths to the eye are useful. If the cellulitis occurs as a complication of some exhausting disease, hot stupes should be used. When suppuration is inevitable, it should be hastened by warm fomentations or poultices, and pus should be evacuated by a long Graefe cataract knife or a narrow straight bistoury. In doubtful cases it is well to make an exploratory puncture. The knife is entered at the margin of the orbit, and its point is kept near the wall as it is passed toward the apex. The wound is kept open by a tent, or a small drainage-tube is inserted. If there is empyema of an accessory sinus, the sinus should be opened either through the orbit or through the nose.

Tenonitis.—The capsule of Tenon is a fibrous envelope of the eyeball derived from the dural sheath of the optic nerve, and lined by a serous membrane which, according to some authorities, is continuous with the arachnoid. The eyeball moves in this envelope like the head of a bone in its articular capsule. The capsule is intimately connected with the sheaths of the muscles, which pass through it at the equator of the ball, and in the neighborhood of the corneal margin it is merged in the conjunctiva and subconjunctival tissue. By means of the anterior ciliary arteries it is connected with the intra-ocular circulation. Tenonitis occurs occasionally in facial erysipelas or as a rheumatic affection, but more frequently it is a result of direct injury or of extension of intra-ocular or conjunctival inflammation. It is the cause of the exophthalmos in panophthalmitis and in some cases of purulent ophthalmia. It sometimes follows an operation on the eye, particularly upon the external muscles. The symptoms are conjunctival and subconjunctival congestion, usually with chemosis, moderate exophthalmos, restriction of the movements of the eyeball, which are painful, and spontaneous pain, which is increased by pressure upon the ball.

Treatment.—Rheumatic cases require hot stupes, cotton compresses, anodyne applications, and the administration of salicylates. In traumatic cases, the application of iced cloths over the eye and of leeches to the temple, and the internal administration of calomel, are useful measures.

Periostitis of the Orbital Walls.—Periostitis of the orbital walls, when located near the margin, as it frequently is, may be detected by pressure with the finger. If located more deeply it causes exophthalmos; and, when it is at the apex, paralysis of some of the external muscles of the eye, from involvement of the nerves at their entrance into the orbit, is likely to occur. The differential diagnosis of the disease from orbital cellulitis and from tumor has already been discussed. Periostitis may be traumatic or rheumatic, or may be due to extension of inflammation from one of the accessory cavities, but is most frequently syphilitic. The local treatment is the same as that of cellulitis. When there is suppuration or excessive swelling free incisions are required. In syphilitic cases mercurials and large doses of iodides should be administered.

Caries or Necrosis of the Orbital Walls.—Caries or necrosis of the bony walls of the orbit is the result of periostitis or of disease of the accessory cavities. It is usually located near the margin. An abscess forms and it either opens spontaneously or is evacuated by surgical means. Afterward there remains a sinus with puckered and adherent edges, and probing reveals dead bone. Probing at the roof or the upper margin of the orbit requires care to avoid injuring the brain. The adherent and contracted cicatrix is likely to cause serious deformity of the lids, and for the relief of this a plastic operation may be required after sequestra have exfoliated or the disease has subsided. Abscesses should be evacuated, kept open by a tent, and syringed daily with antiseptic solutions. It is safer to allow sequestra to exfoliate without much interference beyond keeping a free opening. Mercurials and iodides are required in syphilitic cases, which are frequent, and a long course of treatment with quinine, iron, and cod-liver oil is often necessary.

Hemorrhage in the Orbit.—Hemorrhage into the tissues of the orbit is usually of traumatic origin, though it has occasionally occurred in scorbutic subjects, in sudden suppression of the menses, and from violent coughing. Hæmatomata have been formed by repeated hemorrhages. When hemorrhage occurs after injury of the head it is generally a symptom of fracture of the walls of the orbit. The other symptoms are exophthalmos and ecchymosis of the lids and conjunctiva.

TREATMENT.—Iced compresses are used to check further hemorrhage, and afterward absorption is promoted by hot stupes and a compress bandage.

Emphysema of the Orbit.—This is due to entrance of air into the orbital tissue from rupture of the lachrymal sac or from fracture or some pathological lesion of the walls of the accessory sinuses. The symptoms are exophthalmos and crepitation of the puffy lids. As regards the treatment a compress bandage may be of use, and the patient should be warned against blowing his nose.

The Exophthalmos of Exophthalmic Goitre (Graves's Disease, Basedow's Disease).—Exophthalmic goitre is a complicated disease in which, in its typical form, exophthalmos is associated with enlargement of the thyroid gland, functional disturbance of the heart, and neurotic symptoms. In a large proportion of cases the subjects are females, usually adults under thirty years of age. The sympathetic system is involved, and the symptom described by von Graefe, and known by his name, is due to contraction of the non-striated muscle of Mueller. The upper lid does not follow the upward and downward movements of the ball, but remains more or less fixed and somewhat retracted, giving a staring and startled expression to the patient. The Stellwag symptom is due to the same cause, and consists in infrequent and incomplete winking. Slight keratitis occurs in severe cases, and occasionally sight is lost from ulceration of the cornea. Some authorities attribute this ulceration simply to exposure from the exophthalmos, while others consider it an instance of neuroparalytic keratitis due to disturbance of nutrition. ("Neuroparalytic Keratitis," Harlan, *Am. Jour. of Med. Sciences*, April, 1874.) Vascular engorgement of the orbital tissue seems to be the cause of the exophthalmos. It usually disappears after death, and no constant lesion of the orbital tissue has been discovered post mortem.

Treatment.—The treatment of exophthalmic goitre is discussed in the article on Surgical Diseases and Wounds of the Thymus and Thyroid, in Vol. VI. To protect the exposed cornea it is sometimes necessary to perform a tarsorrhaphy. (See page 566.)

Pulsating Exophthalmos.—This condition is due to obstruction of the venous circulation of the orbit, caused most frequently by a lesion in the cavernous sinus. The eyeball is protruded—generally directly forward—and there is pulsation evident to the touch and to sight. The patient complains of a whirring sound in the head, and an aneurismal bruit is heard on auscultation over the eye and temple. There are usually distention and pulsation of the supra- or the infra-orbital vein, or of both. Deep in the orbit, above the eye, a rather firm and elastic tumor, also pulsating (the distended vein), can be felt. There is more or less pain. Sometimes it is severe. When the carotid is compressed in the neck, the pulsation and bruit cease and the eye can be replaced by pressure. The eye suffers from pressure constantly exerted upon it and may be destroyed by sloughing of the exposed cornea. Death may result from hemorrhage or from exhaustion. The most probable causes of the condition are aneurism of the internal carotid artery or of the ophthalmic at its origin, aneurismal varix between the carotid and the cavernous sinus, usually traumatic, thrombosis of the ophthalmic vein or cavernous sinus, and growths at the apex of the orbit or in the cavernous sinus. Perhaps the most frequent cause is a traumatic or pathological communication between the carotid artery and the cavernous sinus.

Treatment.—The most efficient treatment is ligation of the common carotid, and a number of brilliant successes have been reported. It is a dangerous remedy, however; and, in view of the facts that some cases have remained a long time without material change and that a few have recovered spontaneously or under medical treatment, one should not resort to the operation except after most careful consideration. Holmes has reported a case in which complete cure followed the exhibition of veratrum viride and extract of ergot (*Am. Jour. of Med. Sciences*, July, 1864), and Freeman one that recovered under treatment by the application of cold, by pressure exerted upon the swelling, and by the use of digitalis. (*Ibid.*, 1866.) Compression, continued or intermittent, of the common carotid artery has been successful in some cases (Harlan, Trans. Am. Oph. Soc., 1875). Knapp reports a case in which he successfully extirpated the contents of the orbit, and refers to three others. (*Archives of Ophthalmology*, Vol. XII., No. 2.) In extirpation, hemorrhage is best controlled by the actual cautery. The Paquelin apparatus is convenient.

Vascular exophthalmos without pulsation is sometimes met with. Pulsation and bruit may be absent in thrombosis of the cavernous sinus; and cavernous tumors of the orbit, consisting of spongy tissue encysted in a dense capsule, do not always pulsate. On the other hand, very vascular malignant growths sometimes cause pulsation.

Angioma of the Orbit (Telangiectasis).—An angioma sometimes extends into the orbit from the skin of the lids, forming a soft compressible tumor. Treatment by electrolysis has been successful in some cases (Snell, *Lancet*, July, 1886), but in many others extirpation is required.

Other Tumors of the Orbit.—Tumors of the orbit, other than vascular, are cystic or solid. The most prominent symptom is exophthalmos. If the tumor is situated outside of the muscular funnel, it will cause the eye to protrude in the opposite direction; if it is situated within the funnel the protrusion will be directly forward. The limitation of the movement of the ball is usually less in the latter cases. A large tumor limits the movements of the eyeball, and complete immobility suggests the presence of a malignant growth, as the tendency of such a growth is to include and involve the muscles. The eyeball suffers from pressure, and is likely to be destroyed. Pain is referred to the eye, the bottom of the orbit, the frontal region, or the whole head. The ophthalmoscopic appearances may be negative, but usually there are seen signs of pressure in the form of venous congestion, arterial contraction, retinal hemorrhages, or "choked disc."

CYSTIC TUMORS.—The most common cystic tumors are the sebaceous, which probably arise from the skin. Cysts of the lachrymal gland have already been referred to (page 592), and so also has the peculiar and rare form of cyst known as congenital orbital cyst, with anophthalmos or microphthalmos, or as cyst of the lower lid, with microphthalmos (page 554). Serous cysts have been attributed to disease of the bursa of the superior oblique muscle.

DERMOID CYSTS.—Dermoid cysts of the orbit are not infrequent. Their walls have a cutaneous structure, and they contain sebaceous matter and sometimes hair and teeth. A frequent seat is near the external angular process of the frontal bone—above and to the outer side of the eyeball. They originate as small congenital tumors which tend to increase slowly in size, and may not attract attention until adult life. They are easily extirpated.

Cysticercus Cysts.—A few cases of cysticercus of the orbit have been reported.

Solid tumors of the orbit are frequent and may be of almost any form—as, for example, sarcoma, carcinoma, osteoma, fibroma, lipoma, etc.

Epithelioma.—Epithelioma often extends into the orbit from the skin of the lids, or may originate in the lachrymal sac. (Harlan, Trans. Am. Oph. Soc., 1894.)

Sarcoma.—The most common solid orbital tumors are the sarcomata. They may originate in the orbital tissue or may extend to it from the eyeball or the accessory cavities. The last is probably the most frequent origin. Intra-ocular malignant tumors, when they have forced their way through the sclerotic, extend rapidly in the orbit.

Fig. 321.—Sarcoma of the Orbit. (Harlan, in Trans. Amer. Ophth. Society, Vol. VII.)

Orbital sarcoma sometimes grows to an enormous size. Fig. 321 is from the photograph of a patient, nine years of age, in the Wills' Hospital. The disease originated in the orbital tissue and involved the eyeball and nose secondarily.

Lymphadenoma.—Lymphadenoma has been mistaken for sarcoma. Even microscopically it has a close resemblance to small-celled sarcoma. Examination of the lymph nodes, the blood, and the general condition of the patient may clear the diagnosis, which is important, as the disease may yield to time and proper medical treatment, and should not be treated surgically.

Tumors of the Optic Nerve.—These may consist of glioma, myxoma, sarcoma, endothelioma, or carcinoma. (Knapp, Trans. Internat. Med. Congress, 1876.) Protrusion of the eyeball takes place in a direction nearly parallel with the axis of the orbit.

Osteoma.—Osteoma of the orbit may grow from the bone, or originate in the periosteum. It is likely to involve one of the accessory cavities. It sometimes has a cancellous structure, but generally is dense (*ivory exostosis*). It is of slow growth, but in some cases has attained a great size—even filling the orbit.

Treatment.—The only treatment of orbital tumors, except in case of syphilitic gummata or lymphadenomata, is operative. If vision is good or the eye sound, the eyeball should be preserved if possible, but in case of extensive malignant growths it is usually necessary to sacrifice it and to remove all the contents of the orbit ("*exenteration of the orbit*"), including the periosteum. The ball is enucleated in the usual way, or may be removed with the diseased mass. The external canthus is freely divided; and the lids, if not involved in the disease, are dissected free and retracted. The tissues around the orbital margin are incised with the scalpel, and with the flat knife handle, periosteum-scraper, or large blunt, curved scissors (enucleation-scissors) the mass is freed on all sides and down to the apex; and the attachments of the muscles and the optic nerve are severed with the scissors while the tumor is drawn out with a tenaculum or a loop of thread passed through it. The forefinger passed behind it assists in turning out the mass. The periosteum is incised around the orbital margin, peeled from the walls with the periosteum-scraper, and cut out with the scissors. Bleeding is arrested with wads of absorbent cotton saturated with very hot water, and pressed firmly into the cavity; or, if necessary, the actual cautery may be employed for the purpose. In some cases it may be necessary to apply chloride-of-zinc paste to the bared walls, or to sear them with a hot iron; but this is not without some danger. The cavity is packed with iodoform gauze or with lint saturated with boro-glyceride. The latter prevents the dressings from adhering to the tissues and so facilitates their removal on the second or third day. The treatment of malignant growths of the orbit is rather discouraging. According to Bull, removal is almost invariably followed by recurrence, and the growth of the secondary tumor is more rapid than that of the first (Trans. Am. Oph. Soc., 1896). The life of the patient may be shortened. Nevertheless, some years of comparative comfort are sometimes secured. When the disease involves the neighboring cavities, the propriety of operation is questionable.

Smaller growths and those of non-malignant character may be removed without seriously disturbing the eyeball, particularly if they are outside of the muscle funnel. This has been done even in cases of tumor of the optic nerve (Knapp and Gruening, *Arch. of Ophthalmology*, Vol. IV., p. 323, and Vol. V., p. 508.) Tumors outside of the muscular funnel are removed through an incision of the skin along the orbital margin. The orbital tissue is separated by a blunt instrument until the tumor can be felt, when it is grasped by a tenaculum or a pair of forceps, drawn forward, and freed from its connections. A tent is sometimes inserted in the wound.

To remove a tumor of the optic nerve, an incision is made in the conjunctiva over the outer part of the ball. The tendon of the external rectus is divided, secured by two threads, and drawn aside, while the tumor is exposed by separating the orbital tissue, and the nerve is divided on each side of it with the blunt, curved scissors. The tumor is drawn forward and dissected free. The external rectus is then re-attached by means of the sutures. (Knapp, Lagrange.) The removal of tumors situated deeply in the orbit is facilitated by temporarily resecting the external wall of the orbit by the operation devised by Kroenlein. The following is Knapp's description of the operation: "A curved incision (Fig. 322) is made from the temple over the upper outer part of the orbital margin through the skin on the nasal side of the outer orbital margin, curving back into the temple above the zygomatic bone (*s s*). The incision is carried down to the bone along the outer orbital margin. The periosteum on the inner surface of the external orbital wall is detached with a raspatory as far as the anterior end of the lower orbital fissure, into which a sharp-pointed probe is inserted to serve as a land-mark. A wedge-shaped piece ($a\ a^1\ a^2$) is now separated from the outer bony wall of the orbit by chiselling from the upper end of the margin obliquely down ($a\ a^1$) to the inferior orbital fissure, and then horizontally from the lower end of the margin of the outer bony wall (a^2) to the anterior end of the inferior orbital fissure. The chiselling is not easy, for the bone is hard, readily splinters, and is thick and firm at the lower end of the outer orbital wall. A flat, sharp chisel should be used, working with gentle hammering into the bone with its corner, not with the whole sharp edge, which might splinter the bone. The piece of bone thus circumscribed is about 3 cm. high and from 3 to 4 cm. long. It remains in contact with all the soft parts on its edge and outer surface, which are subservient to its nutrition. If the periosteum which lines the inner surface of the outer wall is not diseased, it has only to be split to expose the posterior part of the orbital cavity, operations in which locality can then be performed with greater precision and more ease than if the outer wall had been left in position. (The piece of bone attached to skin, fascia, and muscle is turned back far enough to give access to the orbit.)

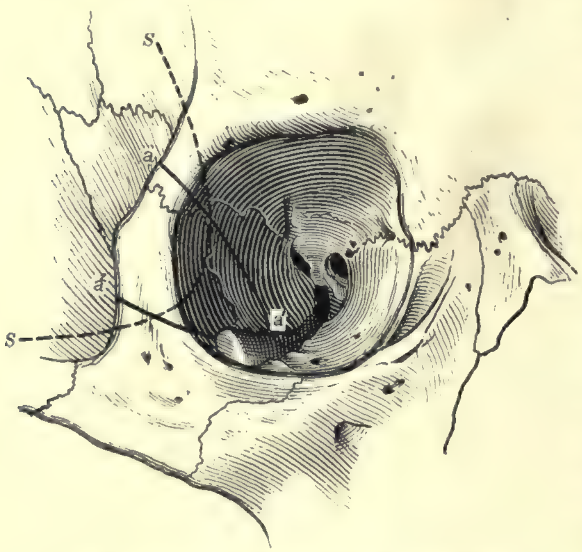


FIG. 322.—Kroenlein's Operation. (Knapp.)

"When the operation on the contents of the orbit is finished, the displaced bone is turned back into its place, and the periosteum is united with catgut and the skin with silk sutures. A compressive bandage and rest secure immobility and smooth healing of the temporarily resected bone."

Exostoses may be removed with comparative safety when they are situated on the floor or on the external or internal wall of the orbit; but when they are on the deeper part of the roof the operation is extremely dangerous. Of sixteen cases, collected by Berlin, in which exostoses of the orbital roof were operated on, six ended in death by meningitis. The attachment of the base of bony tumors to the orbital walls is much less firm than the structure of the tumors, and this should be made the point of attack in removing them. Knapp (*Arch. of Ophthalmology*, Vol. IX., p. 464) describes a method of shelling them out by chiselling the orbital wall that encases them, grasping them with bone forceps, and removing them entire.

Injuries of the Orbit.—Injuries of the orbit include contusions, fractures, lacerated or punctured wounds, rupture of vessels and nerves, and entrance of foreign bodies.

Contusions.—Contusions of the orbital margins are often followed by extensive subcutaneous or subperiosteal hemorrhage. Amaurosis was formerly attributed to contusion or laceration of the supra- or infra-orbital nerve at its exit from the orbit, but this is no longer considered probable. When blindness results from such contusions, it is more likely that the optic nerve has been injured by a fracture involving the apex of the orbit, or that the ophthalmoscope would show some intra-ocular lesion such as rupture of the choroid or hemorrhage in the vitreous body.

Fractures of the Bony Wall of the Orbit.—A simple fissure in the walls of the orbit may cause little or no disturbance unless followed by subperiosteal hemorrhage or periostitis. But fracture with displacement of fragments is almost constantly indicated by more or less extensive hemorrhage, with exophthalmos and ecchymosis of the lids and conjunctiva, which are important symptoms in fracture of the skull. Complete blindness after fracture of the orbit generally results from rupture of the optic nerve, but may be due to hemorrhage within its sheath. Fracture of the base of the skull frequently involves the orbit. It may be produced by contre-coup from a blow on the top of the head. In post-mortem examinations of eighty-six cases of fracture of the base of the skull, von Holden found fracture of the orbit in seventy-nine.

Wounds.—Lacerated wounds of the skin about the orbit generally heal quickly under antiseptic dressings. They may require sutures. The swelling caused by subperiosteal hemorrhage is as hard as a bony tumor.

Punctured wounds of the orbit are likely to injure the optic or ciliary nerves, the muscles of the eyeball, or the eyeball itself. Penetrating wounds of the roof of the orbit are almost necessarily fatal from injury to the brain. Berlin records forty-one deaths in fifty-two cases.

Foreign Bodies.—Foreign bodies, even of considerable size, may remain undetected in the orbit. Carter has reported a case in which a piece of an iron hat-peg remained in the orbit for some weeks without injury to the eye or the knowledge of the patient; and Noyes one in which, five months after the accident, he discovered the breech-pin of a gun four and a half inches long, one inch wide, and a quarter of an inch thick, in the orbit, where its presence had not been suspected, though it had penetrated the roof of the orbit and the brain. The patient subsequently died of cerebral abscess.

Dislocation of the Eyeball.—Dislocation of the eyeball is usually the result of violence. The ball is forced out between the lids, and the orbicularis muscle contracts behind it. The optic nerve, though violently stretched, may escape permanent injury if the dislocation is promptly reduced. Dislocation also sometimes occurs spontaneously in cases of pronounced exophthalmos due to various causes. In a case of recurrent spontaneous dislocation, without previous exophthalmos, I could discover no cause but extreme relaxation of the muscles of the eyeball and the lids, and congestion of the orbital tissue. It was necessary to perform tarsorrhaphy.

Enophthalmos.—Enophthalmos, or sinking of the eyeball into the orbit, may be idiopathic or traumatic. The appearance that it presents has been compared to that of a badly fitting artificial eye. Idiopathic enophthalmos occurs, in wasting diseases, from absorption or atrophy of orbital fat. von Graefe observed it in cholera patients to such a degree that the upper lid curved backward. It has been attributed in some cases to paralysis of Mueller's unstriped orbital muscle, or to atrophy of orbital tissue from trophic disturbance, and has been met with in connection with trifacial neuralgia. It is one of the symptoms of paralysis of the sympathetic. Paralysis of the oblique muscles tends to produce it.

Traumatic enophthalmos is usually due to fracture of the orbital bones and is thought to be caused by displacement of the walls and enlargement of the orbital space or to subsequent cicatricial contraction of orbital tissue. This contraction may also result from chronic cellulitis, and sometimes follows operative procedures in the deeper parts of the orbit.

In the treatment of injuries of the orbit it is a point of the first importance to make sure that no foreign body is present.

In all manipulations the proximity of the brain should be remembered.

Cold applications are useful, and cellulitis may be relieved by leeching at the temple. If pus forms, it should be promptly evacuated by free incision.

A dislocated eyeball is replaced by stretching and drawing forward the upper eyelid while the ball is pressed back. It may be necessary to perform canthotomy.

Empyema or growths in the accessory cavities often involve the orbit. They are discussed in another part of this work.

XVII. PROTHESIS OCULI.

Prothesis oculi is not only desirable from a cosmetic standpoint, but often necessary to prevent or relieve a condition of irritation.

The exposure of the contents of the orbit, the falling in of the lids, with entropion, and the consequent mechanical irritation by the lashes, often set up a severe conjunctivitis, the discharge from which inflames the skin of the face and produces a condition which is most disfiguring and annoying. All this may be remedied by a properly fitting artificial eye, which also, to a great extent, prevents the atrophy of the orbit and face that ensues when an eyeball has been removed from a growing child.

Artificial eyes were applied to mummies by the Egyptians and to statues by the Romans, but the first mention of their prosthetic use in the living occurs in the writings of Ambroise Paré. (Trousseau.) Not much progress was made in their manufacture and application until the beginning of the last century, but at the present time they are used in all civilized countries, and their manufacture has become quite a considerable industry. The materials universally employed in their manufacture are glass and enamel. Copper, celluloid, and vulcanite have been tried, but without success.

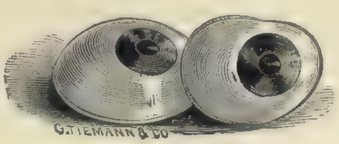


Fig. 323.

The "shell" (Fig. 323) represents the anterior segment of the eye, and its edges fit into the conjunctival cul-de-sac. The attachment of the external ocular muscles to the capsule of Tenon gives a certain degree of motion to the artificial eye in unison with that of the other, but this, of course, is far from perfect.

The greatest defect in the patient's appearance results from the sinking in of the fold of skin above the upper lid, which takes place when it has entirely lost the support of the ball. The disfiguration is less in those individuals in whom a partially shrunken ball remains or in whom an artificial ball of glass or other material has been inserted in the emptied sclerotic or the ocular capsule. (See Mules's operation, p. 646.) An artificial eye is not usually well borne if any clear cornea remain in the stump. Sometimes the furrow above the lid can be partially hidden by the use of a rather heavy spectacle or eyeglass rim.

In the application of an artificial eye it is advisable not to use too large a shell. It should be of such a size that the lids can close over it readily; and, if the conjunctival sac will hold only a very small one, it may be given the appearance of larger size by having the patient wear a convex lens in front of it. It is important that the edges of the shell shall be, not sharp, but rounded, and its surface should be perfectly smooth so as not to cause any friction. A new eye should be substituted as soon as there is reason to suspect that the one in use is not entirely smooth. When an artificial eye has lost its polish it irritates the conjunctiva and sets up a conjunctivitis which may end in contractions that will render the further use of an artificial eye impossible. Even sympathetic disease of the sound eye has resulted from the irritation of a roughened and ill-fitting artificial one. A shell usually becomes unfit for use in from one to two or three years, or earlier, according to the quality of the material of which it is composed and the nature of the conjunctival secretion.

After enucleation or abscission, an artificial eye should not be inserted until the conjunctiva is entirely free from inflammation,—usually not for two or three weeks, or perhaps longer, if there has been a considerable degree of conjunctivitis before the operation. Nor should its use be too long deferred, as the lids and conjunctival sac will contract. In case of inflammation of the sac, the eye should be removed at once and not worn again until treatment has restored the normal condition of the conjunctiva.

The artificial eye is always removed at night, washed with fresh, clean water and absorbent cotton, and put away in an aseptic box. It should be handled only with aseptic hands. The orbital cavity should be douched morning and night with boric-acid solution. The eye and the cavity must be kept aseptic.

A peculiar shape of the cavity or a cicatricial conjunctival bridle may require a special form of shell, in which case the patient should be sent to the manufacturer to be fitted. This is perhaps the best course to adopt in any case, as the color of the sound eye can then be accurately copied and the shell can be given the exact form required.

To introduce an artificial eye, the following plan should be adopted:—while the patient looks up, the upper lid is drawn forward, and the broader side of the shell is slipped beneath it and pushed into the orbital cavity. At the same time the lower lid is drawn downward until the edge of the shell passes over it, and then the lid is allowed to resume its natural position. If, after this, the patient looks down, the edges of the shell will be found to rest in the upper and lower culs-de-sac. To remove the artificial eye, the end of a strabismus-hook or the head of a large pin is inserted under its lower edge and drawn forward, while the patient looks up. Little gold pin-like instruments are sold for the purpose. Patients soon acquire the knack of introducing and removing the eye quickly and easily. Until they have acquired the necessary degree of skill they should hold the head over some soft substance, as a folded towel, while the artificial eye is being manipulated.

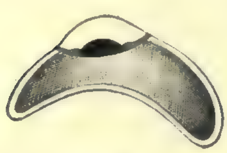


Fig. 324

In the last few years the so-called "reformed eye" has been in general use. The advantages claimed for it are that its edge is blunter and less likely to cause irritation and that it fills the cavity better. It has double walls enclosing a cavity. (Fig. 324.) Although the name of Snellen has, in some way, been associated with this new form of artificial eye, it was really first introduced by J. L. Borsch, a Philadelphia optician, in 1894, and was exhibited to the ophthalmological section of the College of Physicians in February, 1897, by Dr. Schwenk. It was not used or seen by Snellen until 1898. While a few surgeons do not prefer it to the old form, this new form of artificial eye is now in very general use, and whatever credit attaches to its introduction is due to Borsch. The "reformed eye" generally breaks much less easily than does the old one, but several curious cases have been reported in which it cracked without evident cause and with quite a loud report. It is supposed that the intense heat used in the manufacture makes a vacuum within the walls of the shell and that a sudden jar or a violent pressure of the lids causes fracture by atmospheric pressure. It has been suggested to make a hole in the wall to admit the air, but, as it would also admit secretions, it is probably better to take the chances of this very rare accident.

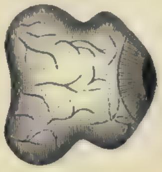


FIG. 325.

Borsch has also made an artificial eyeball for use in exceptional cases. It has a very deep socket and relatively small conjunctival sac, in which the small shell that can be introduced sinks back into the orbit. (Fig. 325.)

SURGICAL DISEASES AND WOUNDS OF THE EAR.

By ROBERT LEWIS, JR., M.D., New York City.

I. AURICLE.

Congenital Malformations of the Auricle.—Congenital malformations of the auricle may be due either to an arrested or to an excessive development; they may be unilateral or bilateral.

Malformations due to arrested development include: (*a*) Absence of the whole or of parts of the organ; (*b*) microtia (diminutive ear); and (*c*) congenital aural fistulæ. The cases belonging to the latter class are by far the most important, as a lack of development in other portions of the auditory apparatus is often found associated with this condition.

(*a*) Absence of the Whole or of Parts of the Organ.—The external auditory canal, the membrana tympani, the ossicular chain,—one or all of these may be rudimentary or wanting; or the labyrinth may be only partially developed; and even the lack of development may include the maxillary, sphenoid, and palatal bones, and the structures of the throat. In some cases a lack of cranial development is found. There may be complete bony or membranous closure of the external auditory canal; the external orifice may be a mere depression; there may be a constriction at some portion of the canal or it may be uniformly narrowed.

Gruber describes a case in which the right auricle was very rudimentary and the external auditory canal was entirely wanting. In addition, the following abnormal conditions were observed: The right half of the forehead was more prominent than the left; the left zygoma was smaller than the right; the right naso-labial fold was obliterated; the right eyeball remained partially exposed when the patient attempted to close the eye, and he was not able to wrinkle the skin of the forehead on the same side; the right side of the soft palate was lower than the left, and the uvula was drawn over to the left side; when the patient made an attempt at whistling, the mouth was drawn to the left; the sense of taste was normal; air entered the Eustachian tubes on catheterization; the watch was heard on contact; and the sound of a vibrating tuning-fork placed on the vertex was best heard on the defective side. This case showed defective development of the peripheral portion of the facial nerve as well as a lack of development of the auditory apparatus and the zygoma.

Virchow, cited by Gruber, considers that deformities of the auricle are to be regarded as connected with faulty morphological development in the region of the first branchial cleft.

Congenital absence of the entire auricle is very rare, as some portion of the auricular cartilage covered with integument is generally to be found. Defects of particular portions of the auricle are more common and possess, except from a cosmetic point of view, but little pathological importance. In this category belong: those cases in which the normal inrolling of the helix may fail to take place, and as a result we then have the ape-like auricle, or Darwinian pointed auricle; those in which the antihelix is larger than, and overrides, the helix—the "Wildermuth auricle"; and, finally, those cases in which the auricle is lapped over on itself ("cat's auricle"), with or without the growing together of the helix and tragus.

(*b*) Microtia.—Microtia is comparatively rare; the ear, though diminutive, may be well developed, or it may be malformed. When this latter condition is present it is often found that the malformed ear occupies some abnormal position, as in front of or below its usual location—a possibility which should always be remembered if an operation to form an external auditory canal is attempted.

(*c*) Congenital Aural Fistulæ.—Congenital aural fistulæ are to be found, sometimes associated with other deformities of the ear or with branchial fistulæ, sometimes in otherwise normal ears, in front of the tragus or in the ascending portion of the helix. They are not, as a rule, true fistulæ, but short blind canals, from 2 to 6 mm. in depth, lined with an epithelium that produces a white creamy secretion, which secretion may cause an eczema of the neighboring skin. They are liable to mild inflammatory attacks, with the formation of an abscess from closure of the entrance. They are often hereditary. They occur as the result of non-union between the various lobules which coalesce to form the auricle. Congenital fissures—a condition to which the term coloboma lobuli has been applied—are to be found in the lobule.

Malformations due to an excessive development include: (*a*) supernumerary appendages; (*b*) abnormal development of a part or of the entire auricle (macrotia partialis vel totalis); and (*c*) supernumerary auricles (polyotia).

(*a*) Supernumerary Appendages.—These are most often seen occurring singly or in a chain in front of the tragus, on a line with one of the transverse clefts, and are composed of reticulated cartilage with its coverings of perichondrium, subcutaneous areolar tissue, and skin. Such a structure must therefore be considered to be a true auricular appendage. They are to be found of appreciable size, and sometimes fibres of the muscles of the face are found in them. They occur either with other deformities of the ear or with a normal auricle.

(*b*) Macrotia Partialis.—Macrotia partialis is not rare and is often found among the women of those races which wear heavy ear-rings. In such women the lobes are often found to be of an enormous size. Macrotia totalis is rare.

(*c*) Polyotia.—Polyotia is extremely rare. Lauger relates the cases of two double-bodied monsters each of which had four auricles.

The most frequent and most readily corrected of the malformations of the auricle are those in which the cephalo-auricular angle measures fifty-five degrees or over. This latter condition is not always congenital, but is frequently caused by a faulty style of dressing the hair or of using strings in adjusting the headgear. For this reason it is more frequently to be found among women.

Prognosis.—In cases of malformed auricle, when there is an absence of an external auditory canal and the tuning-fork is not heard by bone conduction, it is best not to attempt any operative interference unless it be for cosmetic reasons. In cases of unilateral deformity in infants it is almost impossible to state whether they hear or not, and it is therefore best to give an unfavorable prognosis.

Treatment.—In the correction of some of the above-mentioned defects otoplasty is of service, but its range is limited. In cases of imperfect meatus a normal tympanum is the exception, and experience shows that it is practically impossible to prevent a recurrence of the closure of the canal after operation. It is often best, in a case of marked auricular deformity, to remove the entire auricle, with the exception of a stump, to which an artificially devised auricle may be fastened. (See article on Prosthesis, etc., in Vol. VI.)

Supernumerary appendages may be removed, or, if associated with auricular defects, they may be utilized in correcting the latter at some later date. When they are removed, care must be exercised not to cut too deeply, as some of the branches of the facial nerve might be wounded.

Congenital aural fistulæ should be opened throughout their entire length, the lining membrane should then be carefully exsected, and, finally, the whole cavity should be thoroughly curetted and the wound then allowed to granulate.

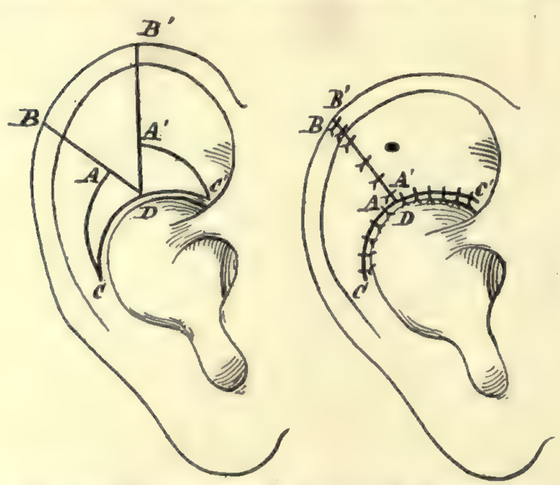


Fig. 326.—Operation for the Removal of a Wedge-Shaped Portion of the Upper Ear. (From Stone, after Cheyne and Burghard.)

Excessively large ears may be reduced in size by an operation of which the following are the two fundamental features (see accompanying Fig. 326, taken from Stone's article on "Plastic Surgery," in Vol. IV.): the removal of an elliptical piece of cartilage ($ACDC'A'$) from the fossa of the helix, and the excision of a triangular section (BDB') from the posterior border of the helix. The apex of this triangle should be located in the posterior portion of the concha. After the removal of these two portions of the auricle, the edges of the wound are to be united with fine interrupted silk sutures.

In the so-called "cat's auricle" the holding of the auricle in a correct position by means of adhesive strips or bandages may remedy the deformity. At the same time, if adhesions are found to exist between the helix and the tragus, they will have to be cut through, and if the cartilage is not sufficiently flexible it may also have to be cut through along the line which marks the folding. In some cases it may be necessary, in addition, to hold the auricle upright by denuding a small area on its posterior surface and a similar area on the side of the head, and then causing these two denuded surfaces to adhere together. (Fig. 327.) Every case will call forth a certain amount of ingenuity on the part of the operator.

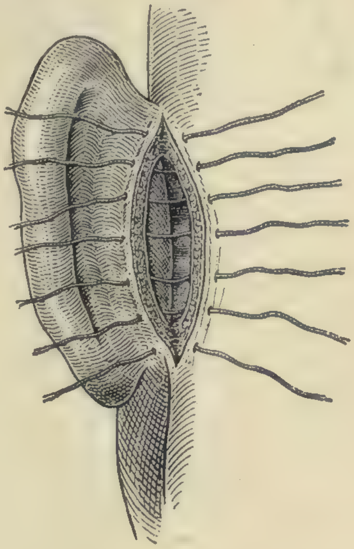


FIG. 327.—Shows the removal of the elliptical portion of skin from the posterior surface of the auricle and from the skin over the mastoid process, and the method of uniting the surfaces.

Malposition of the Auricle.—The normal cephalo-auricular angle is considered to be between fifteen and thirty degrees. It is only in cases where the auricle flares (handle-shaped ears)—*i.e.*, where the auricle is attached to the head in such a manner as to form an angle of over fifty degrees—that an operation is indicated for cosmetic reasons. The deformity, if not too marked, may be corrected in childhood by wearing close-fitting caps day and night for a long period, so as to press the auricle close to the head. The cap should be made of some thin material and the crown should be cut out so that it may exert only such pressure as is absolutely necessary on the expanding skull of the child, and at the same time may heat the head as little as possible.

In children of older growth and in adults it will be necessary to perform a plastic operation. It is needless to say that the most thorough asepsis is necessary in the performance of the operation. The surgeon should also be very careful to remove only so much tissue as is necessary to bring the cephalo-auricular angle to a point between fifteen and thirty degrees, if both ears are to be operated upon; if only one ear is at fault, greater care still is necessary in order to make the angle of the one to be operated upon correspond with that of its mate.

OPERATION.—An elliptical piece of skin, extending from just above the lobule to a point where the posterior surface passes forward to form the upper surface of the organ, is removed from the posterior surface of the auricle. (Fig. 327.) From the cartilage thus exposed a similar section is removed; and, in doing this, the operator must be careful not to wound the skin covering its anterior surface. It is best to remove too little rather than too much, for if, upon bringing the edges of the cut surfaces together, it is found that the angle is still too large, a further portion of tissue may be removed. The edges of the wound in the cartilage should meet and not over-ride each other. The external wound is closed by means of a subcutaneous suture of silkworm gut or of interrupted sutures of siver wire. No sutures should be used to bring the cartilaginous edges together, as they will be brought into coaptation by the closure of the wound in the skin. The dressings are left in place for a week, when the suture should be removed and a light dressing applied and held in place with collodion. A bandage should be worn at night for several weeks.

To make the incision directly through all the tissues of the auricle renders it difficult to bring the wounded edges together, and leaves a visible scar on the anterior surface of the auricle.

In some cases the deformity is not marked, and in these it may not be necessary to remove a portion of cartilage; but in the vast majority of cases the results are more satisfactory when a section of cartilage is removed. The deformity is then less likely to recur.

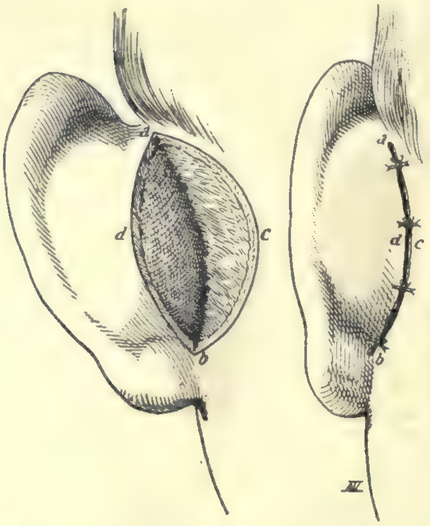


FIG. 328.—Diagrams Showing the Method of Remedying the Condition Known as "Cat's Auricle." (Laurens.)

Duell's Operation.—The following operation, devised by Duell for protruding ears, is analogous to Panas' operation for ptosis:*

"The skin on the back of the auricle is grasped by rat-toothed forceps at two points, from one-half to one inch apart and about one-quarter inch behind the free border of the helix. By slight changes of the position of these forceps and dragging the auricle by them back to the scalp, the most advantageous points for, and the direction of, the pull necessary to correct the deformity are determined. These points are then marked by dark indentations made by a hard squeeze of the forceps.

"Parallel incisions through the skin are then made, slightly longer than the distance between these marks, one at the post-auricular angle, the other about one-quarter inch behind this. The skin is dissected up forming a thick loop.

"Parallel lines are now cut from the points previously marked on the auricle to the anterior border of the loop. The resulting band of skin is dissected up to the points from which the traction should be made. Care should be exercised to avoid any injury to the perichondrium in this dissection. A pair of forceps is now passed under the loop, and the band of skin is grasped and drawn beneath it. This band being as a lever and the loop as a fulcrum, the ear is now drawn back into the desired position.

"It is necessary at this time to have the loop held down tight to keep it from stretching, and to spread the band to its full width by grasping the free corners with the rat-tooth forceps.

"The desired position of the ear having been secured, the points on the band which come under the loop should be marked, as well as the distance from the posterior border of the loop to which the end of the band extends.

* Archives of Otology, xxxvii., No. 1.

"The band is now pulled out, and, being stretched over a small pad of gauze, is superficially denuded over the area which is to lie under the loop. A quadrilateral piece of the scalp corresponding to the area which will be occupied by the end of the band is next dissected out. The band is now again drawn under the loop, the denuded surfaces are accurately apposed, and all edges are united by interrupted sutures.

"A thin pressure pad is placed over the line of sutures between the scalp and the auricle, a generous one is placed over the auricle, and a tightly fitting bandage is applied. The dressing should be left on a week, when the stitches may be removed and another pressure dressing applied, as before, for another week.

"It is needless to say that asepsis is essential to success. It can readily be seen that this operation will correct the most exaggerated protrusion of an auricle without interfering with the cartilage, while at the same time it will preserve the normal depth of the sulcus behind the ear."

Burns and Scalds.—Burns and scalds of the auricle are rare. Such an injury may be inflicted through caustic or hot liquids or molten metals being thrown at or falling upon the head, or, as often happens, by the patient's falling accidentally, or being pushed, against a hot object—*e.g.*, a stove, a steam-pipe, etc. All grades of burning are observed, as in the case of other parts of the body. While these burns of the auricle are generally of a superficial character, Hartmann of Berlin has reported a case in which the damage inflicted was sufficiently severe to cause a perichondritis. When the burns involve the walls of the auditory canal or the drum membrane the condition is a serious one. Permanent perforations in the drum membrane, stenosis of the canal, synechiæ between the walls of the canal or between the drum membrane and the walls of the tympanic cavity, permanent loss of hearing, and facial paralysis may result. Among the more serious consequences reported may be mentioned: purulent infection with caries of the osseous walls of the canal and of the tympanic cavity, as also of the ossicles; mastoiditis; and infective meningitis with fatal results.

Pernio; Frost-bite.—In this affection we find various degrees of inflammation, according to the degree and the duration of the cold. The lighter forms are characterized by a bluish-red coloration, an ordinary amount of swelling, and very severe itching, which may increase to pricking pains. In other cases, which have resulted from exposure to a more intense cold, the auricle appears extremely swollen, very much reddened, and covered in various places with large blebs, the contents of which are of a yellowish or bloody color. The pain is apt to be very great. The severest forms are seldom seen. In these gangrene develops; there is a black discoloration and abscesses form. Ultimately the ear shows varying degrees of deformity. Ears that have been frozen still continue to be sensitive whenever the temperature falls to a certain point. In these cases the swelling, the itching, and the development of nodules, which may go on to form pustules and to ulcerate, often recur. In weakened individuals, especially young anæmic girls, frost-bites and chilblains are likely to develop at the beginning of cold weather.

Treatment.—In the lighter forms of freezing, the application of cold compresses and poultices containing Goulard's extract will be found sufficient; in extreme hyperæmia and swelling there should be a continuous application of cold by means of Leiter's coil. In regard to the itching and pain, relief may generally be obtained by the local use of tincture of iodine to which tincture of opium has been added. Afterward, ichthyol ointment should be applied. The following preparations will also be found useful: boric acid or zinc ointment; ointment of silver nitrate (two per cent); or an ointment containing orthoform. In the deep ulcers and also in exuberant granulations, silver nitrate stick should be used. Gangrenous parts should be amputated.

The ears should be protected from cold by ear muffs, and they should receive frequent washings with absolute alcohol. In anæmic cases the general health should be looked after.

For the relief of the itching an ointment of camphor may be used or the following solution applied:—

℞	Ol. terebinth....................................	ʒ i.
	Ol. ricini..	♏ xx.
	Collodion	℥ i.
M.		

Incised and Lacerated Wounds.—Superficial injuries affecting the auricle are to be treated in the same manner as those which affect other parts of the body. Neglect here, as elsewhere, is likely to lead to infection, and this in turn may cause a perichondritis. Parts of the ear which are severed must be very carefully sewed together. Cases have been reported in which the auricle, after being entirely severed, has been sutured in its proper place, has taken a firm hold, and has healed without deformity. When this operation is performed, the surgeon must see that the meatus is kept open and not allowed to become closed by the formation of new tissue. This is necessary for the preservation of hearing. Hemorrhage must be controlled, not by ligatures, but by means of a suture transfixing the bleeding vessel. The edges of the wound should be very carefully brought together,—at times a very difficult matter. Superficial gangrene sometimes occurs, and necessarily gives a cicatricial appearance to the surface after healing has taken place.

The artificial opening for ear-rings is apt to be torn through, and as a result inflammation may develop in the wound. A very simple plastic operation will correct the resulting deformity, and for the performance of this operation local anæsthesia will be found sufficient.

While othæmatoma may in certain cases, as stated further on, arise without previous injury, it is dependent in most cases upon trauma of the ear. It is a noteworthy fact that othæmatoma is seldom seen in the army. In lunatic asylums, furthermore, it has become less frequent since the patients have received more humane treatment. The capacity for hearing is not materially lessened by injuries inflicted upon the auricle, even when the loss of substance is considerable.

Othæmatoma (Blood Tumor).—Othæmatoma is an exudation of blood into the subcutaneous connective tissue of the auricle, or under the perichondrium, or into the substance of the cartilage. Generally, the swelling appears suddenly on the surface of the auricle, in the antihelix, or in the concha, and quickly reaches a certain size. In some cases the tumor may be as large as a hickory nut, or it may even involve the whole upper two-thirds of the ear. The swelling, when the subcutaneous structures are alone involved, is hemispherical, fluctuating, with a smooth surface and at times a bluish color. (Fig. 329.) The skin covering the tumor is intact. Fluid blood or bloody serum constitutes the contents of the mass. Where the extravasation is under the perichondrium the depressions and elevations of the auricle are definitely outlined. In many cases there is pain at the outset, but seldom are there other evidences of inflammation. Left to itself, an othæmatoma, in the course of time, undergoes absorption, or else it remains as a local thickening between the folds of the ear. If inflammation sets in, which may result from the bruising and subsequent necrosis of the tissues and the entrance of bacteria into the extravasated blood, the symptoms may be quite severe. Otherwise, the only symptoms will be a change in the form of the auricle and a certain feeling of pressure. If the area involved is quite large, the swelling may cause closure of the external auditory meatus and so give rise temporarily to tinnitus and deafness.

Fig. 329.—Othæmatoma in the Upper Part of the Auricle. (After Buerkner.)

In the greater number of instances the othæmatoma is found to be of traumatic origin, occurring in those whose ears are much exposed to injuries (such as boxers and prize fighters, acrobats, porters, etc.), or in the insane who have chronic dementia and subject themselves to numerous small injuries. In old, decrepit persons othæmatoma does occur without trauma, and is then due to atheromatous degeneration of the blood-vessels. Finally, it may occur as a purely idiopathic affection in conditions of mental derangement and without an antecedent traumatism.

Fig. 330.—Othæmatoma of the Auricle, with Areas of Destructive Chondromalacosis, Resulting in Marked Diminution in Size of the Entire Organ. (After Benni in Comptes Rendus du Troisième Congrès International d'Otologie, Bâle, 1858.)

Deformity of the auricle to a greater or less extent is nearly always a result of othæmatoma. Fig. 330 represents one of the strange and characteristic forms which the organ may assume after healing takes place. The appearance of the auricle is the same, it may be said, whether the disease occurs in lunatics or in the mentally sound. Obliteration of the sac is accomplished by the union of its walls, and, where the perichondrium has been greatly stretched by extreme distention, it contracts upon itself as reabsorption takes place, and perfect adaptation of the skin to the cartilage cannot occur. The misshapen appearance of the organ increases with the continued contraction that takes place during the process of adhesion. The ear finally becomes indurated, the skin on the outer surface immovable. Sometimes the organized lymph which obliterates the cavity enormously increases the thickness of the auricle; but, where the intervening plastic layer is thin, the auricle will be reduced in size, and often becomes quite thin and shrivelled.

In a few cases the hæmatoma is confined to the lobule alone. The disease develops in the form of a circumscribed, soft, purplish-red swelling, more or less sensitive to the touch. This swelling results from a hemorrhage into the subcutaneous areolar tissue. Owing to the exposed position of the lobule it is often subjected to injury, but a simple hæmatoma is of very infrequent occurrence in this locality. Consequently, when we encounter this lesion in the lobule of the ear, we have a right to suspect that the blood-vessels of the part are diseased, especially if any brain affection or some general disturbance of nutrition should be present at the same time. The diagnosis of a hæmatoma in this situation is not difficult. The sudden appearance of the tumor and the discoloration make the confusion with angioma or some other form of neoplasm impossible; and, as perichondritis never occurs in the lobule, the hæmatoma cannot be mistaken for it. In transmitted light the swelling is not translucent.

Treatment.—The treatment in certain of these cases is expectant—the simple application of cold compresses. Puncture or incision is certainly not to be advised, except in such cases as become infected. In these cases evacuation of the cavity, with removal of any bits of necrosed tissue by curettage, is immediately indicated. Afterward, small pledgets of sterile gauze should be applied to the irregular surface of the auricle in such a manner as to retain as nearly as possible its contour, and over this a bandage should be so adjusted as to exert gentle pressure. Daily dressings will be necessary. Massage may be used after the tissues have become united to the cartilage.

Perichondritis.—Perichondritis generally begins in the external auditory canal and is associated with œdema of the tissues. As a rule it extends to the concha and thence to the other parts of the auricle, until often the whole organ is converted into an irregular, fluctuating mass, in which the folds and prominences of the auricle are obliterated. The meatus is stenosed and the lobule alone remains free from involvement, being separated by a sharp line from the other parts. An increase of the local temperature is present. The neighboring lymphatics are often involved and may become the seat of abscesses; at times, sharp, darting pains, with a sensation of heat, are referred to them. The fluctuating mass, which has formed in the course of a few days, contains a clear, serous, synovia-like fluid, which is never bloody as in the case of an othæmatoma; it soon, however, changes to pus. The course of the affection is either acute, lasting for from three to ten weeks, or chronic, lasting for the same number of months. Healing often occurs without any deformity, but in some cases there is a certain amount of shrinking. In rare cases ossification subsequently takes place. The left auricle seems to be the more frequently affected.

The causative factor may be a local infection of the external auditory canal, or the disease may follow a general infection, as in the case of syphilis. In some instances it develops from a trauma or through extension from a furunculosis, from an otitis externa, or from a purulent affection of the middle ear. Occasionally it occurs as one of the sequelæ of the radical mastoid operation, from infection of the meatal flap.

The diagnosis is very easy to determine. The condition could be confused only with that of othæmatoma in its later stage, when sometimes the bluish-red color of the skin, which is dependent upon the presence of a bloody serous exudate, is succeeded by a paler hue, owing to the conversion of the latter into a transparent syrup-like fluid. The previous history, the course of the disease, and the fact that the lobule is not affected in perichondritis confirm the diagnosis.

The prognosis is favorable, in that healing always occurs even if a deformity results.

The treatment consists, first, in energetic, local, antiphlogistic measures (ice-bags). If these fail to help, one may resort, in the early stage of the inflammation, to warm, wet compresses, and later, if necessary, to incision of the most dependent parts. After the incision has been made it is advisable to remove, by curettage, the necrosed cartilage and the fungous granulations, and then to irrigate the cavity thoroughly with antiseptic fluids. As final steps a gauze wick should be introduced for drainage purposes, and small pledgets of sterile gauze should be applied on the outside in the hope of thereby preserving the contour of the auricle. The wound should be dressed daily. After the parts have healed massage may be employed to advantage.

Tuberculous perichondritis of the auricle has been described by Haug. It affects the concha, which is red and doughy to the touch. The neighboring lymph nodes are also swollen and are sensitive to pressure. The skin over the swelling is somewhat red or bluish in color, but it may be pale; it cannot be indented. It must be borne in mind that these tuberculous nodules resemble fibromata, which are common in this region, and consequently a differentiation must be made between the two diseases. In general, these tuberculous nodules grow very slowly, and only rarely do they show an inclination to soften and break through on the outside. According to Haug, nodular tuberculosis arises from an infection with tubercle bacilli in connection with piercing the ears, or as a result of wearing ear-rings which were previously worn by tuberculous patients.

The disease is of slow development. If the nodules are not operated upon, abscesses develop, after the lapse of a certain length of time, and tuberculous ulcers of the skin make their appearance. Then follow fistulæ, through which necrosed cartilage can be felt with a probe. If the swelling is incised at an early stage and widely opened, discolored pus and granulations containing tubercle bacilli will be disclosed, and the affected cartilage—sometimes in the form of a disconnected sequestrum—will also be seen. In cases that are not operated upon early the disease lasts for a period of many months, and deformities of the ear often result.

The prognosis of nodular tuberculosis is relatively good, and if the nodules and affected lymph nodes are operated upon and removed early, a complete cure may be looked for.

Lupus is seldom observed. Treatment consists in the excision of the pathological area, to be followed by a plastic operation for cosmetic purposes. The Roentgen ray, the violet ray, Finsen's light, have all been used with varying degrees of success.

Ossification of the Cartilage of the Auricle.—A few instances of this affection have come under observation. In these cases the cartilage was always found to be partially but never wholly affected; the upper part of the cartilage, the helix, the scaphoid fossa, the antihelix, and the fossa triangularis were the localities affected, while the tragus, antitragus, and lobule remained perfectly free.

Ossification does not seem to occur with special frequency at any particular period of life; it has been observed in persons as young as fifteen and in others as old as seventy-five. In a large proportion of the cases the change represents the termination of an othæmatoma; in still other cases a simple perichondritis, or a perichondritis the result of a frost-bite, has been observed to give rise to the deposit of bone. In many instances the cause is to be sought in trophic changes. These newly deposited bone masses possess all the anatomical features of true bone; the Haversian canals being surrounded by well-formed bone corpuscles, marrow, etc. The process goes on without visible appearance of inflammation and without the subjective symptom of pain. Treatment is scarcely required. Knapp has in one case extirpated the bony cartilage.

Ulceration.—Ulceration may occur as a complication of burning or freezing; it is also observed in ecthyma, in herpes, in otitis externa diffusa, in diphtheria, and in gangrene. Such ulcers are generally seated on the tragus, the concha, or the lobule. They are superficial and they soon heal if suitable antiseptic dressings are applied. On the other hand, if they are allowed to become deep-seated, they are very slow in healing and are often the starting point of a severe eczema. Every eczema may give rise to numerous small ulcers. Ulceration of the auricle may also be due to syphilis or to a tuberculous or simple perichondritis.

The ordinary ulcerations do not extend to any great depth, and are covered with a yellowish, watery exudate. Those of a syphilitic nature present more marked characteristics: they are deep, crater-like excavations with sharply defined, indurated borders. They are often seen when the chancre has been overlooked. The favorite site of a secondary syphilitic ulceration is the hole pierced for the ear-ring in the lobule; the mechanical irritation supplied by the ear-ring at this point favoring the development of papular infiltration and the formation of small ulcerations on the anterior and posterior surfaces of the lobule. In tertiary syphilis, if the ear is affected by the ulcerative destruction of the gummatous new growths, the underlying cartilage is apt to become the seat of inflammatory action.

Primary syphilitic infection of the auricle has been seen and described by Zucker. The case was that of a man whose ear had been licked by a syphilitic woman. The auricle became swollen, ulcers formed upon the anterior surface of the tragus, and the neighboring lymph nodes also became very much swollen. Occasionally the contamination of the ear with syphilitic secretion, as after contact with dirty hands or other infected objects, has caused a primary infection of this organ.

The prognosis and treatment of ulcers of the ear depend largely upon the causative factors.

Gangrene.—Gangrene of the ear is seldom seen. Sometimes it affects the skin alone; at other times the cartilage is also affected; but there is always more or less extensive loss of substance. As causes we have a preceding wound or an abscess such as results from measles, erysipelas, or burning and freezing of the third grade. Urbantschitsch reports a case of Raynaud's spontaneous symmetrical gangrene in the upper third of the ear; it was caused by trophoneurotic disturbances. In the majority of cases the inflammatory process is of long duration and depends on a disturbance of nutrition caused by thrombosis of the vessels. Treatment must consist in the removal of the necrotic tissue and in accelerating the formation of a line of demarcation. The last may be accomplished through the use of antiseptic poultices. Nourishing diet and tonics are indicated. Skin-grafting may be found necessary.

Noma.—Noma is a very infrequent affection and has been observed, up to the present time, only in ill-nourished, young children, especially after typhoid fever, the acute exanthemata, or diphtheria, and mostly in association with otorrhœa.

The diagnosis and prognosis are the same as for noma of the cheek. The disease is to be treated locally by daily applications of silver nitrate, or by means of the Paquelin or galvano-cautery; the gangrenous parts are also to be removed with a curette. Constitutionally the treatment should be of a stimulating character, with a liberal diet.

Erysipelas.—Erysipelas of the ear is of rather common occurrence. It takes its rise here either primarily, from injured or excoriated spots (*e.g.*, piercing of the lobule with unclean instruments for the suspension of ear-rings; from the wounding of the external auditory canal with unclean instruments (while removing cerumen or a foreign body from the canal), or, secondarily, from extension from the face, or from the throat through the Eustachian tube and middle ear. The clinical picture, the course, and the termination are the same as when the disease affects other parts of the body. The auditory meatus, at least in the outer part, is generally involved, and occasionally the disease may extend to the membrana tympani. In those cases in which a perforation occurs the inflammation may extend from the middle ear to the mastoid cells. Repeated attacks may cause hypertrophy of the skin of the auricle and external auditory canal, and the resulting stenosis of this canal may be accompanied by a temporary diminution of the hearing.

An efficient plan of treatment is to apply to the affected part ichthyol ointment, which both relieves the tension of the skin and keeps the infectious scales from being disseminated. Poultices saturated with one-half to one per cent bichloride solution have been recommended. Ordinarily the further spreading of the erysipelas has been prevented through frequent pencillings of the neighboring sound parts with a strong tincture of iodine, or by scarifying this area. The general condition and the complications demand suitable treatment.

Abscess.—Abscess of the auricle may occur in connection with skin affections, such as eczema, especially where pruritus is marked; the infection being conveyed by dirty finger nails or in some similar way. An abscess may also develop as a result of freezing or of an erysipelatous attack. Finally, it may develop from the sting of an insect or from a trauma of any kind, such as piercing the lobe, etc. Swelling, redness, pain, a sense of heat, and fluctuation are the symptoms which indicate the presence of an abscess of the auricle. The condition may become dangerous through a spread of the infection to the cartilage, thus causing a perichondritis. When a perichondritic abscess develops the cartilage is often destroyed, with a resulting deformity, or fistulæ may form.

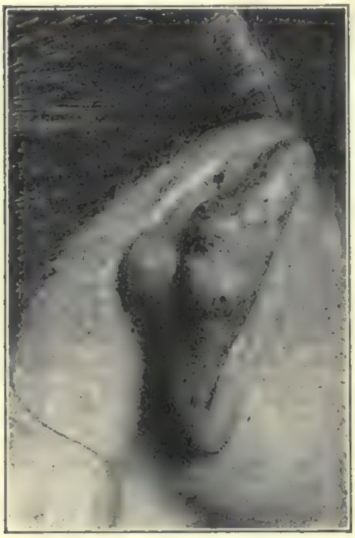


Fig. 331.—Angioma of the Outer and Posterior Aspects of the Auricle. The tumor consists of three nodules, the outer one of which is double. (Author's case.)

An early free incision, curettage, and the application of wet sterile dressings constitute a suitable method of treatment.

Benign New-growths.—The following benign new-growths of the ear have been observed: angioma, atheroma, chondroma, chondro-myxoma, cysts (both serous and dermoid), fibroma, lipoma, nævi, and papillomata (warts).

Angiomata.—Angiomata of the auricle are of relatively frequent occurrence. They vary in size from that of a hempseed or lentil to that of an egg. (Fig. 331.) Their color varies from red and bluish-red to blackish-blue. They are soft, rounded, and provided with knobby prominences of the skin and subcutaneous tissues. Pulsation is sometimes present, and the patient complains of a throbbing sensation. At times there is marked tinnitus. These growths are observed on the anterior and posterior aspects of the auricle, on the tragus, at the entrance of the canal, and on the lobule,—involving, consequently, the branches of the auricular, occipital, and temporal arteries. The smallest ones often manifest themselves as vascular naevi, which reach various degrees of development.

The angiomata of the auricle often remain unchanged in size for ten or more years. On the other hand, there are cavernous angiomata which grow with extraordinary rapidity, forming large knotty tumors. Most angiomata of the ear and its surroundings are congenital, but cases have been observed in which they have developed as a result of a burn or of freezing, as also from the effects of traumatism. A true aneurism only rarely originates in this way. Pedunculated angiomata are rare.

Injuries often lead to hemorrhages which are difficult to check; spontaneous bursting from momentarily increased blood pressure, such as takes place during coughing, vomiting, etc., may occur. One case of death has been observed as a result of the bleeding from spontaneous bursting of a blood-vessel of the auricle.

The morbid anatomy of these angiomata is the same as that of other angiomata; that is, they are considered to be formations of enlarged blood-vessels with simultaneous thickening of the vessel walls, or they are due to the formation of new blood-vessels. They are to be reckoned among the benign tumors only so long a the process of hypertrophy is confined to enlargement of the vessel walls and to formation of connective tissue. In this category belong the simple angiomata, the cavernous angiomata, and the angio-fibromata. As malignant melanotic sarcomata develop at times from a nævus vascularis, these tumors ought to be completely eradicated.

Prognosis.—The prognosis is good if the efferent vessel or any of the collateral branches are obliterated and if the vascular mass is entirely removed. Failure, through recurrence, arises from neglect of these two conditions.

Treatment.—Complete extirpation of the tumor, and the successful obliteration of the vessel or vessels which supply the tumor with blood, constitute the proper treatment. In cases of large tumors it may be necessary, in order to prevent the re-establishment of the collateral circulation, to tie the common carotid, and this is deemed justifiable if, when pressure is made on the common carotid, the pulsation in the tumor is diminished. In cases where the growth is of smaller size, ligature of the anterior or posterior auricular or of the external carotid or of the internal maxillary artery may suffice. After this has been accomplished the skin covering the tumor should first be carefully dissected away from the growth, and then the latter should be removed from its bed intact. No suspicious vascular tissue should be allowed to remain. If the skin has been free from disease, the field should be thoroughly cleansed, and the raw surface of the skin should be held in close apposition to the underlying tissues by a sterile dressing and pressure bandage. If the skin, however, is diseased and the underlying cartilage exposed, skin grafting will have to be resorted to. If asepsis is perfect very little after-treatment will be necessary. Injections of liquor ferri subsulphatis and other similar methods of treatment are dangerous because of the possibility of an infecting thrombus being formed.

Electrolysis is the best one of the non-surgical methods of treating these growths. The needle is connected with the positive pole and should then be inserted into the tumor, while the negative pole is placed elsewhere upon the body of the patient.

A few cases of angioma of the external auditory canal have been observed. Angiomata of the drum membrane, with a pulsation that was synchronous with the heart-beat, with bulging and redness of the drum membrane, have been reported by Buck and Weir. Destruction by means of the cautery point is the best method of treating such growths.

ATHEROMATA (SEBACEOUS CYSTS).—These cysts are usually found in the lobe of the ear, but they have also been seen in the concha and on the posterior surface of the auricle, rarely in the meatus. They are caused by the blocking of the duct of a sebaceous gland. The sac may rupture and thus afford escape for the contents, which consist of degenerated epithelial cells, sebum, and cholesterin crystals.

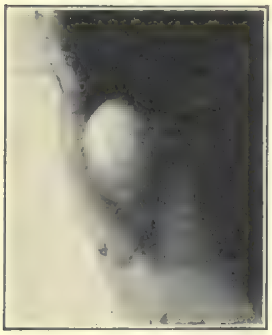


FIG. 332.—Atheroma or Sebaceous Cyst of the Left Auricle. Patient was born with a small tumor, about the size of a pea, on the back part of the left ear. It increased very slowly in size until four months previous to her visit to the Infirmary. It then became painful and increased rather rapidly in size. When removed at the operation it measured 36 × 36 mm. (Author's case.)

Treatment.—Incision over the greater convexity of the tumor and careful dissection so as to remove the sac entirely, without rupture of its walls (as was done in the case illustrated in Figs. 332 and 333), constitute the best method of treating these tumors. If located in the meatus the cyst may occlude the canal and give rise to tinnitus and deafness, and if not removed it may cause erosion by pressure. These cysts may also break down and suppurate. They should be removed by excision, if possible, as in the case of atheroma of the auricle. If excision is not practicable, the tumor should be incised and curetted and the parts then allowed to heal by granulation.

CYSTOMATA.—Cysts develop for the most part in the scaphoid fossa of the auricle, in the form of a soft, fluctuating mass. They contain a yellow, thin, sterile fluid, or one which is more or less tenacious in character. It is only seldom that they contain a purulent fluid. They are often found lying between the perichondrium and the skin, but generally they are seated between the two layers of the cartilage. Rupture of the cartilage seldom occurs. The duration is from a few days to many years. Microscopically, the cartilage shows hyaline degeneration.

Treatment.—In general, it is sufficient to incise the tumor and evacuate its contents; in some cases, however, it will be found necessary to resect the upper or both layers of limiting cartilage. Healing occurs in a short time, and with little or no deformity. If possible, the tumor should be removed by dissecting out its sac.

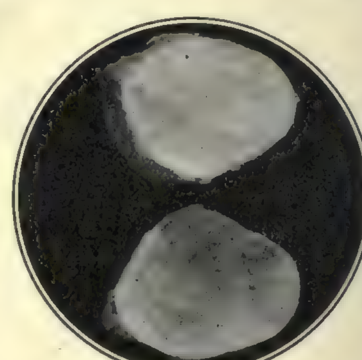


FIG. 333.—Surface of Section of the Sebaceous Tumor is shown in the upper object. The lower object represents one-half of the cyst wall or shell after the removal of the sebaceous contents.

FIBROMATA (KELOID).—Fibroma is more often observed in the ear than is any one of the other kinds of new-growth. It usually occurs in the lobule, although it has been seen in the concha.

The growths are more common in the negro. Irritation from wearing heavy ear-rings appears to be a causative factor; so also is the mere piercing of the lobule.

A fibroma of the ear is usually very hard and possesses an even surface. It may grow to be larger than the auricle itself. The growth is made up of fibrous tissue, with but little cellular structure. Cases of myxo-fibroma, lympho-fibroma, and fibro-chondroma have been reported.

Thorough removal of the growth is the only method that will prevent its recurrence. To sacrifice healthy tissue is better surgery than to have a recurrence. Sutures should not be employed for uniting the edges of the wound, but in their place strips of sterile zinc-oxide plaster should be used.

Fibromata have been found to exist in the external auditory canal. Fibromata of the tympanic cavity were originally granulomata in which a connective-tissue transformation has taken place at some later date.

Tophi.—Tophi are deposits of uric-acid salts in the auricle; they are regarded as one of the earliest symptoms of gout. They appear here more frequently than in any other part of the body. They vary in number and in size. Sometimes they are white and contain a milky or creamy fluid; at other times they are as hard as little stones and are firmly attached to the cartilage by an inflammatory exudate. The patient afflicted with these deposits experiences, both before and during an attack of gout, a sensation of smarting and pricking in these nodules. In some cases these deposits make their appearance for the first time shortly after an attack.

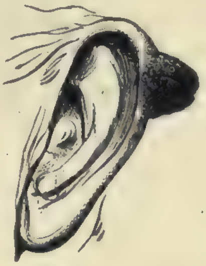


Fig. 334. — Cornu Humanum of the Auricle, about one-half natural size. (After Buck.)

Hypertrophies.—Hypertrophies are sometimes congenital, sometimes acquired. Under this heading are classed: nævus pigmentosus, nævus vascularis, and nævus cysticus; verruca vulgaris; cutaneous horns; those skin troubles which, starting in other parts of the body, affect the ear by extension or otherwise (*e.g.*, ichthyosis, scleroderma, and elephantiasis); and, finally, the thickenings which follow othæmatoma, perichondritis, the different inflammations, traumata, and freezing.

A *nævus* or *mole*, whether of the pigmented, the vascular, or the cystic variety, is a congenital anomaly which develops *pari passu* with the growth of the body, but causes no constitutional disturbance. It is seldom observed on the ear. (Pipino.) In old age the change of moles into malignant new-growths (epitheliomata) has been observed.

The treatment is preferably surgical—by excision and suture; the galvano-cautery may also be used.

Papillomata (warts) should be removed by excision. A less desirable method is to remove the growth by the application of fuming nitric acid, pure carbolic acid, or trichloracetic acid, or by means of the galvano-cautery. After the tumor has been excised it is always wise to cauterize the base so as to prevent recurrence. Papillomata generally occur on the lobe; they have in rare instances been observed on the drum membrane.

The *cutaneous horn* should not be regarded as a neoplasm, but as a pure hypertrophy of the skin. It consists of squamous epithelial cells, hypertrophied papillæ, and fibrous tissue, with a small blood supply. Its attachment to the skin is very slight, and the growth may easily be removed, but it will generally recur if the base is not cauterized after its removal. Buck reports a case where the horn grew to be three-quarters of an inch in height and three-quarters of an inch in breadth at its base. (Fig. 334.)

The hypertrophic skin diseases—ichthyosis, elephantiasis, and scleroderma—are very seldom seen as independent affections of the auricle.

Malignant New-growths.—Among malignant tumors the more important are the sarcomata in their different forms. The relatively benign fibro-sarcoma is found in the lobule as well as on the other parts of the ear. It is only by the aid of the microscope that a distinction can be made between such varieties of new-growths as the angiosarcoma, the chondroma, the cylindroma, etc.

Etiology.—The etiology of these growths is obscure. Scars, erosions, moles, a chronic eczema, a nævus, etc., may all serve as starting-points. Sarcoma of the auricle affects, as a rule, individuals under fifty years of age. The different forms vary as to the rapidity with which they grow. The round-celled sarcomata affect the auricle very seldom, while the fibro-sarcomata are the most common among the new growths of the ear. The primary nodule often remains for quite a long time relatively stationary until it receives some traumatism—the usual cause of a renewed activity of growth. This lighting up of the disease may manifest itself either in the form of superficial erosions, which bleed easily, secrete a thin serum, and have their edges markedly infiltrated, or in that of the rodent ulcer, which is of slow development and is situated in the skin and perichondrium. Lupus or syphilis is often mistaken for epithelioma, especially when the characteristic eruptions are wanting, and when, in the neighborhood of the ulcer, neither macular nor papular infiltrations are to be found. In both cases the neighboring lymph nodes are swollen. But in gumma other areas of swollen lymph nodes are to be found. A course of antisyphilitic treatment will clear up the diagnosis. The microscope will be of assistance if true epitheliomatous tissue is found, but if the microscopic examination is negative it is not proof positive that a malignant growth is not present. The disease (epithelioma) spreads from the auricle to the canal, and thence to the tympanic cavity and the internal ear. A fatal result may be brought about by the involvement of the meninges, or of the brain substance.

Symptoms.—Severe pain, located deep in the ear, and facial paralysis are among the most striking symptoms. Deafness and tinnitus may develop if the labyrinth becomes involved; paralysis of the abducens, of the oculomotor, and of the trigeminal nerves may occur from extension of the infection.

The epitheliomata are therapeutically accessible only in the early stages, and they yield only to extensive excision. The entire auricle, the soft structures of the external auditory canal, the parotid gland, and all the lymph nodes in the vicinity should be removed. The employment of caustics tends rather to accelerate the growth of these tumors, and this remark applies with equal force to all other modes of treatment.

In the slowly developing carcinomata there is an abundant formation of connective-tissue stroma, which gives a thick, tough structure. On the other hand, in the more malignant type we have a stroma rich in vessels and in embryonic connective-tissue cells. In this variety there is developed a rich, thick layer of typical strings of cells which grow through the whole substance of the cartilage, and, after destroying the capsule of the cartilage, they take its place.

While the rodent ulcers can be removed by operation, even relatively late, with good results, in the case of the deep-seated cancers, unless taken at the very earliest stage, the involvement of tissue is so great that excision is not always practicable. In both cases the infiltrated lymph nodes should be removed.

Plastic Operations for the Formation of a New Lobule of the Ear.—The formation of a new lobule of the ear may be necessary because of the congenital absence of this part of the auricle, or because it is the seat of some pathological condition which necessitates its removal.

Gavello's Method.—The method of G. Gavello, of Turin, is as follows:—A transverse incision (c^1e^1, Fig. 336) is made through the lower part of the auricle

FIG. 335.

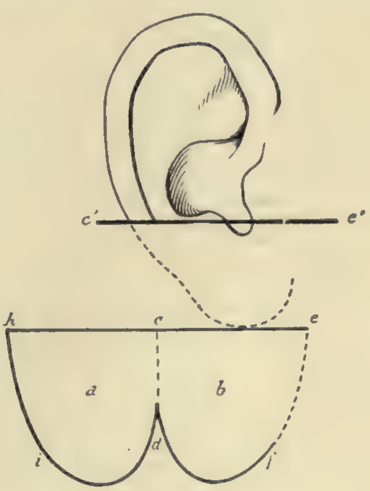


FIG. 336.

FIGS. 335 and 336.—Diagrams Illustrating Gavello's Method of Forming a New Lobule. (Laurens.) In the case, for example, of a new growth of the lobule (Fig. 335), Gavello removes all that part which is diseased by amputating the lower part of the organ below the line $c'e'$. Then he secures the material for a new lobule from the side of the neck in the immediate vicinity (Fig. 336, *hcefdi*). For a further description of the manner in which he accomplishes this, see the main body of the text.

at such a level that the amputated portion will include all of the diseased tissue. Then, on the side of the neck, beneath the auricle and as nearly as possible on a level with the denuded portion of the auricle, Gavello makes another horizontal incision (*hce*), twice as long as the width of the base of the lobule which it is proposed to form. From the posterior extremity (*h*) of this incision another incision (*hidf*), having the shape of an exaggerated *w*, is made. The area of skin between these two incisions is then dissected up, and from this is formed a flap which remains attached at *ef*. The posterior part (*a*) of this flap is folded inward along the line *cd* and made to apply itself to the anterior portion (*b*)—raw surface against raw surface. The edge of the portion *a*—from *i* to *d*—is then united by sutures to the edge of the portion *b*—from *d* to *f*—and the edge from *h* to *i* is united to the tissues immediately behind the line of attachment (*ef*) of the flap. The upper border of the flap (from *c* to *e*) is united to the anterior portion of the denuded edge of the auricle, and the border from *c* to *h* is united to the posterior portion of the denuded edge of the auricle. The skin is partially freed along the lines of incision of the area originally denuded to make the flap, and the line *hidf* is united to the line *hcef*.

The Method of Nélaton.—In this method the lower portion of the auricle is denuded as is shown in Fig. 337, and the incision is extended downward through

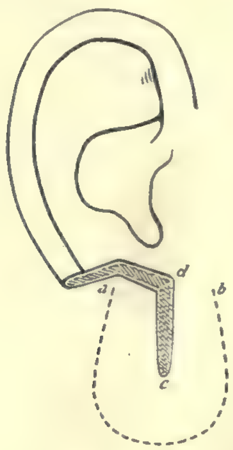


Fig. 337.

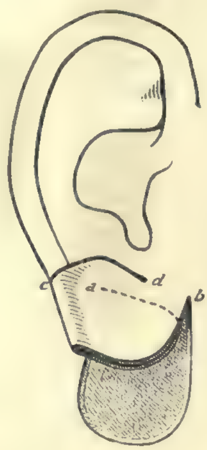


Fig. 338.

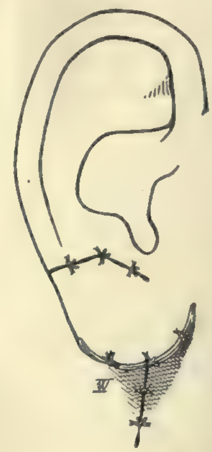


Fig. 339.

Figs. 337, 338, and 339.—Diagrams Illustrating Nélaton's Method of Forming a New Lobule. (Laurens.) The details of the method are given in the main body of the text.

the skin of the neck, from *d* to *c*. An elliptical incision (*ab*, Fig. 338) is made in the neck below the auricle. The skin included in the area bounded by this elliptical incision is then dissected up, and there is thus formed a flap with its line of attachment at *db*. The posterior half of this flap is folded underneath the anterior half of the flap, thus bringing point *a* in apposition with point *b*. The flap is then twisted round into the position shown in Fig. 338. The denuded surface *dc* is united by sutures with the denuded surface of the auricle, and the half of the free edge of *ab* is united to the other half at the point which may be termed the pedicle of the flap. The denuded surface of the area from which the flap was taken is easily covered by bringing together the edges of the skin, as is shown in Fig. 339.

II. EXTERNAL AUDITORY CANAL.

Wounds.—The external auditory canal is rarely the seat of wounds or of injuries. Fracture of the bony canal may occur from a blow, a fall, or a kick, or it may result from gunshot injuries or from the unskilful use of instruments in removing a foreign body. In the case of a blow or fall on the chin, the seat of the fracture is generally the anterior inferior wall of the canal. The superior wall of the canal is involved when the force of impact is on the top of the head, and the posterior wall when the back of the head is the seat of the violence.

The fracture may be confined to the canal alone, or it may involve the tympanic cavity, as well as the petrous or the mastoid portion of the temporal bone. Fracture of other bones of the skull often occurs as a further complication.

The symptoms depend upon the extent of the injury. Hemorrhage, slight or profuse, is always a marked symptom. Deafness and tinnitus are present, especially if the membrana tympani is ruptured. When the labyrinth is involved, marked deafness results, and, in addition, there are tinnitus, dizziness, vomiting, and headache, together with a serous discharge (cerebro-spinal fluid) from the external auditory canal. As a result of such fractures deafness may become total and permanent. If infection occurs, the injured bony wall may undergo necrosis, with the formation of sequestra and the subsequent development of stenosis of the canal. The tympanic cavity may become the seat of an acute purulent otitis media, and the mastoid cells may become infected, the latter condition sometimes resulting in a sigmoid-sinus thrombosis. In addition, instances of inflammation of the labyrinth, of meningitis, of facial paralysis, and of salivary fistula have been reported. Even in cases which at the onset seem to be of but little import, a guarded prognosis must be given because of the possibility that infection may occur a considerable time after the injury and may lead to a fatal issue.

Treatment will have to depend upon the nature and extent of the injury. If, when the patient is first seen, a firm blood-clot has sealed the site of the fracture it is best not to disturb it, as it forms the best protection from infection. Other cases will require cleansing and drainage; packing the canal with pledgets of sterile gauze may also be necessary. In a case of gunshot wound in which the missile is lodged in some part of the ear, or in a case of stab wound in which the point of the weapon has broken off, an operation will be necessary to remove the foreign body. Complications that arise will have to be treated according to the general principles of otological surgery. These injuries frequently are of decided medico-legal importance.

Stenosis and Atresia of the External Auditory Canal.—As has been said above on the subject of malformation of the ear, the canal may be obliterated as the result of congenital pathological anomalies. In addition, atresia and stenosis of the canal occur as the result of an inflammation of its periosteal lining, such as takes place in circumscribed and diffuse inflammations of the external auditory canal, and in cases of chronic purulent inflammations of the middle ear. (Fig. 340.) Ulceration and necrosis of the tissues of the canal take place, and in the reparative process cell proliferation is so exuberant that the canal becomes gradually obliterated by the building up of tissue from its surface on the opposite walls; or the whole lining surface of the canal may become involved and adhesions form with entire, or almost entire, obliteration of its lumen.

The new-growth consists principally of epithelium and connective tissue; sometimes cartilaginous tissue is present, and very rarely bone cells are to be found.

The atresia may be located either in the cartilaginous or in the osseous portion of the canal. It is often associated with other deformities of the ear.

Treatment.—In determining whether to operate or not upon a case of stenosis or atresia of the external auditory canal, much will depend upon the history of the case—upon the mode of origin of the lesion, the previous state of the hearing, the presence (in stenosis) of a purulent discharge from the ear, etc. Once treatment is begun it requires much patience and perseverance to accomplish the desired result and prevent a recurrence of the stenosis or atresia. In stenosis a gradual absorption of the thickened tissues may be accomplished by the use of gauze strips or by the introduction of rubber tubing in a stretched state into the canal. When the tubing, after being placed in position, is allowed to contract to its normal length, there will be an expansion of its calibre, and the rubber cylinder will exert pressure upon the walls of the canal. A continuance of this pressure will in course of time effect a marked thinning of these walls. In atresia the nature and extent of the occluding tissue will influence greatly the decision as to what means shall be adopted for restoring the canal to its normal size. When the atresia is due to a simple membranous mass (a mere diaphragm), it may be exsected around the circumference of the ring, and the canal then packed (and kept packed) to prevent the recurrence of granulation tissue which will again form a septum.

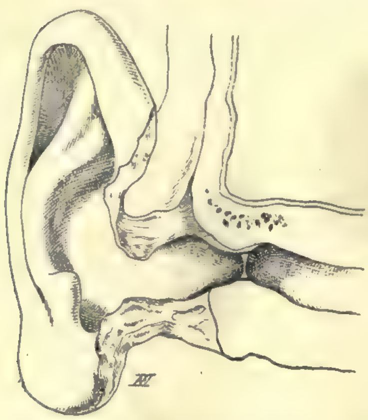


Fig. 340.—Membranous Stenosis of the External Auditory Canal. (Laurens.)

If the area denuded by operative interference is very extensive, skin-grafting ought to be attempted. The grafts should be held in place by glass tubing, or, if possible, flaps may be made of the obstructing septum. The underlying tissues should be curetted away down to bone, and the flaps should be replaced and held in position by gauze packing. If the tissues contain much bone it may have to be removed by the chisel or drill, and skin-grafting resorted to.

Osteomata.—Osteomata occur in the meatus and are not uncommon. (Fig. 341.) They occur singly or in pairs, are found in the osseous portion of the canal, and may grow to such a size as completely to occlude the canal. They may have a broad base or attachment, or they may be connected with the underlying bone by a very thin pedicle. They are generally discovered by chance, as they give rise to no symptoms except in cases where they are very large. The deafness and tinnitus sometimes observed in these cases are due to the obstruction caused by the tumor or, as is more often the case, to the presence of a collection of epithelial detritus behind the tumor.

Treatment.—The early removal of the tumor, while not absolutely necessary in the majority of cases, is nevertheless advisable; for an attack of acute purulent otitis media in an ear the external canal of which is blocked by an exostosis might very readily, because of the presence of such an obstructive tumor, and consequently because of inadequate drainage, extend into the mastoid cells. On the other hand, immediate removal is clearly indicated in the case of a purulent otitis, or in one of eczematous or other inflammation of the canal, for securing better drainage and for facilitating the cleansing of the parts. Removal is very easy in the pedunculated variety, as here a slight blow or a prying motion of the gouge will snap off the growth.

Fig. 341.—Exostosis from the Superior Wall of the External Auditory Canal. (Laurens.)

When the exostosis is more deeply situated, and especially if it is of ivory-like hardness and has a broad base, the operation is much more difficult. If the tumor is situated on the superior, posterior, or inferior wall, in the depth of the canal, and if it have a broad base, it is generally advisable to make an incision through the cutaneous tissues back of the auricular groove, to retract the auricle and posterior canal wall forward, and then to separate the growth from its attachment at its bony base without destroying any of the overlying tissues. The gouge or the chisel is preferable to the drill for the purpose. The margins of the incision made behind the ear should be brought together with a subcutaneous suture, and, if there has been no purulent discharge from the middle ear or canal, the latter should be packed with sterile gauze. The dressing should be changed at the end of five or six days, the suture removed, and the wound covered with a light dressing, which may be held in place with collodion; the canal should also be repacked. In case there has been a previously existing purulent discharge, the dressing of the canal will have to be attended to daily or every other day. But by the method here suggested, if the surgeon has succeeded in separating the skin of the canal (and tumor) from its bony support without wounding it, there is scarcely any likelihood that the wound will become infected by the discharge from the middle ear. As a matter of course, the operation field must be made sterile and strict asepsis practised. Another method is to make an incision through the tissues at the base of the growth, to reflect them back, and to preserve them from injury so that they may be used to cover the site of the growth after its removal. The tumor is gradually undermined and removed piece by piece, the skin flap is used to cover the denuded area of bone, and the canal is packed with a strip of narrow sterile gauze.

Instances of osteoma of the ossicles have been reported. Osteomata of the tympanic cavity have been found post mortem.

Chondromata.—Chondromata are to be found at the entrance of the meatus.

The symptoms are about the same as, though somewhat less marked than, those which characterize an osteoma. The method of removal is essentially the same in both kinds of tumor.

Foreign Bodies in the External Auditory Canal.—Either by accident or by design foreign bodies frequently gain access to the external auditory canal. Unless pushed in by unskilful attempts at removal, the foreign bodies are generally found in the beginning of the meatus.

Insects, such as flies, bed-bugs, sheep ticks, and the Texas screw-worm, have been found in the external auditory canal, and, from the history of the case and the appearance of the parts, the inference is justified that the living creature has used the canal as its habitat for months. The Texas screw-worm, which is capable of penetrating bone, has been reported as invading the cranial cavity by way of the external auditory canal and causing a fatal meningitis.

If, upon inspection, it is found that the canal and adjacent parts are swollen and inflamed, presumably through clumsy attempts at extraction, it will be best to wait until the inflammation has subsided, so that more space may be obtained through which the foreign body may be removed.

To remove the foreign body, the best and simplest way is to use the piston syringe. Warm water, of course, is to be employed. While the syringe is being used the auricle should be grasped and lifted upward and backward so as to straighten out the external auditory canal. It may be found necessary to use the syringe a number of times before the foreign body is dislodged. If this object is of such composition that it will swell under the influence of water, other means may have to be employed. Alcohol may be used instead. If the employment of the syringe prove unsuccessful it will then be advisable to resort to instruments. Anæsthesia is nearly always necessary in children and at times in adults. Then, with a bent probe, a hook, Buck's ring-shaped blunt curette, or a pair of forceps (Sexton's),—depending much upon the size and shape of the foreign body,—its removal can with the exercise of care and patience generally be accomplished. Another method, which, in foreign bodies of a certain character, is often successful, is to dip a camel's-hair brush in glue, apply it to the foreign body, and allow it to become firmly adherent. Then, when traction is exerted upon the brush, the foreign body will be brought away with it.

There have been reported cases in which the attempts at removal of a foreign body have produced disastrous results of an incomprehensible nature. For example, the drum membrane has been punctured, the malleus and the incus have been removed, and the tympanic walls have been injured. Such reprehensible surgery has resulted in acute inflammation of the tympanic cavity, with extension into the mastoid cells, and even fatal cases of meningitis and sinus thrombosis have been reported. It may be necessary, before removal of a foreign body can be effected, to loosen the auricle from its insertion behind, and retract it and the membranous portion of the external auditory canal forward, so as to enable the operator more readily to get at the canal. It may also be necessary to remove a portion of the bony external auditory canal before the obstructing object can be extracted. After this has been accomplished, the auricle is replaced, and a subcutaneous suture is employed for holding it in place until the cut surfaces have united. Stenosis of the canal will be prevented by firm packing.

For the removal of insects such as maggots it may be necessary first to destroy them with a fifty-per-cent mixture of chloroform; oil or water will not always destroy them.

Ceruminous Concretions.—The secretion of the ceruminous glands is normally only sufficient to form a thin oily coating over the skin of the external auditory canal. In some individuals, however, it is secreted in abnormal amount and in denser quality, so that after a time a plug is formed which may entirely fill the lumen of the canal. Patients afflicted with eczema or any hyperæmic condition of the canal are very prone to have an increase in the amount of cerumen. An excessive growth of hair, an exostosis, or other pathological obstruction of the canal may also act as a favoring factor in the production of such an accumulation of cerumen.

SYMPTOMS.—It is often surprising to find how little deafness is present when the canal is clogged with a large plug of cerumen. If the plug presses on the drum membrane or if the whole lumen of the canal is occluded at some one point, the deafness is apt to be more pronounced. When the plug is dry and hard there is apt to be pain, especially when the inferior maxilla is moved. Reflex pains, referred to the mastoid process, are sometimes noted. Other symptoms that have been observed at various times are: vertigo, headache, tinnitus, a sense of fulness in the head and ears, mental depression, laryngeal cough, trigeminal neuralgia, and blepharospasm. Epileptiform convulsions have been reported as the result of impacted cerumen.

A diagnosis of tumor of the brain was made some few years ago by two eminent neurologists, and yet upon the removal of a large plug of cerumen all the symptoms which were thought to be due to a tumor of the brain disappeared.

TREATMENT.—The ceruminous plug should be removed by the forcible injection, by means of a piston syringe, of warm water into the auditory canal. If the plug of cerumen is very hard, it may be wiser to soften it first by means of a solution of sodium bicarbonate in glycerin and water. After this solution has been dropped into the ear two or three times a day for a few days it will be found easily possible to remove the plug by syringing. If too much force is expended upon the piston the patient is likely to experience dizziness, and even fainting may occur, as the result of an increase in intralabyrinthine pressure due to the forced inward movement of the foot-plate of the stapes. The remarks previously made regarding the removal of foreign bodies with curettes or other instruments apply with equal force to the removal of a ceruminous plug.

Otitis Externa Circumscripta, or Furunculosis of the External Auditory Canal.—Furunculosis of the external auditory canal is a circumscribed inflammation involving either the hair follicles or the ceruminous glands of the external or cartilaginous portion of the canal.

ETIOLOGY.—A furuncle may originate in an excoriation of the skin of the canal by the use of infected instruments in the removal of cerumen or of a foreign body from the auditory canal; it may develop as a sequela of eczema or of purulent inflammation of the middle ear; it may also be a manifestation of a general furunculosis, or may result from too frequent bathing in salt water.

Symptoms.—Pain, in some cases intense, is the chief symptom of a furuncle. Allied to it is tenderness, which is most marked when the orifice of the canal is pressed upon or when a probe tipped with cotton is applied with some degree of firmness over the seat of the inflammation. It is by pressure applied in this manner that the site of the furuncle is generally determined, as often, in the early stages, there is no swelling, redness, or other means of ascertaining its location. Later, when the swelling is pronounced, if the furuncle is situated on the posterior wall, one may easily mistake the disorder for a mastoiditis. In furunculosis, however, there is no history of a previous discharge, as is generally the case with mastoid inflammation; there is no deafness; tenderness is elicited when pressure is made upward or forward upon the wall of the canal, while in mastoiditis it will be elicited by pressing from before backward upon the bone. In furunculosis, if a view of the drum membrane can be obtained, it will be found to be normal, which is not the case (except in very rare instances) with mastoiditis. Swelling of the canal in mastoiditis is confined to the upper posterior wall of the inner or osseous portion of the external auditory canal, while a furunculosis is always limited to the cartilaginous portion of the canal, generally nearer the inferior wall. The furuncle, if left alone, ruptures and discharges its purulent contents in the course of about one week.

Treatment.—A five-per-cent solution of carbolic acid in glycerin applied locally may abort the abscess; tightly plugging the canal with gauze may also accomplish the same result. If pus has formed, the walls of the external auditory canal should be thoroughly cleansed and then freely incised over the site of the furuncle. Then the abscess cavity should be curetted so as to remove all necrotic material. As a last step the walls of the abscess cavity should be brushed first with carbolic acid and then with alcohol, and into the cavity should be introduced a small piece of sterile gauze, as furuncles are apt to spread and also to recur. The hygiene and general health of the patient should be carefully looked after.

Otitis Externa Diffusa.—A diffuse inflammation of the external auditory canal may be acute, as the result of the use of some irritating substance (*e.g.*, carbolic acid or iodoform) in the canal; it may be caused by a traumatism (followed by infection) or by burns; it may also represent an extension of an acute purulent otitis media. The presence of vegetable moulds (*e.g.*, the Aspergillus nigricans, Aspergillus fumigatus, etc.) in the canal may also give rise to the disease.

In the simple form of the disease, uncomplicated by the presence of aspergillus germs, the epithelial lining of the canal exfoliates, serum escapes from the tissues, and the meatus becomes filled with a pasty mass. The cutaneous wall of the canal is swollen, reddened, and very sensitive; the hearing is impaired; tinnitus is present; and usually there are itching and some pain. Silver-nitrate solution (from 20 to 60 grains to the fluid ounce) is especially effective as a remedy.

For the removal of the pasty mass in a case that is complicated by the growth of the aspergillus, it is sometimes found helpful first to instil hydrogen dioxide into the canal before an attempt is made to dislodge the plug by means of a syringe filled with a warm saline solution. The dioxide tends to break up the obstructing mass, and so renders it easier to effect its removal. When this has been accomplished the canal should be filled with sixty- to seventy-per-cent alcohol, which should be allowed to remain there for ten minutes. If the alcohol causes pain it may be further diluted. Weak solutions of silver nitrate may also be used with benefit. The treatment here suggested may have to be kept up for a week or more. Relapses are likely to occur, and, to prevent this, the patient's general health will have to be improved. As a preventive measure, the canal should occasionally be filled with the alcoholic solution.

Laminated Epithelial Plugs.—As the result of a chronic inflammation of the canal wall the epithelium peels off and gradually accumulates until it forms a mass which obstructs the canal. Syringing will probably fail to remove the mass because of its cohesiveness; so the curette and the forceps will have to be employed. The continued presence of such a plug in the ear produces a certain amount of erosion, and in consequence the canal undergoes enlargement.

III. MEMBRANA TYMPANI.

There are very few pathological conditions or processes which are confined to the drum membrane. When it is inflamed it is usually because either the middle ear or the external auditory canal, to both of which regions it belongs, is at the same time in a state of inflammation.

Rupture of the Membrana Tympani.—Rupture of this membrane occurs as a result of a blow or a fall upon the side of the head, with or without fracture of some portion of the temporal bone. It may also result from the forcible penetration of a foreign body through its substance. For example, blundering methods of removing a foreign body from the external auditory canal have caused not merely laceration of the canal walls, but also traumatic perforation of the drum membrane, with partial lodgment of the foreign body in the tympanic cavity. The forcing of a bougie through the substance of the membrana tympani from within, by way of the Eustachian tube, and the rupturing of the membrane by the employment of various objects and instruments for the purpose of removing impacted cerumen from the canal (*e.g.*, forcible syringing), as well as by the sudden condensation or rarefaction of the air in the external auditory canal or tympanic cavity (as in gun-firing, diving, ballooning, working in submerged caissons, etc.), illustrate some of the ways in which the lesion which we are now considering may be produced.

When the rupture takes place the patient hears a loud report and experiences pain in the damaged ear. Among the additional symptoms observed are tinnitus, dizziness, a sense of faintness (perhaps actual fainting), vertigo and vomiting. There may be no hemorrhage, or the bleeding may be profuse.

In a majority of the cases healing takes place in a short time with no impairment of function; in other cases the perforation may be permanent, and there may be more or less impairment of hearing. In a few cases the force of the concussion causes a hemorrhage into the labyrinth, with more or less permanent loss of hearing. Infection may take place and the resulting purulent inflammation may be followed by necrosis of bone, granular hypertrophy of the mucous membrane, adhesions between the drum membrane and some portion of the walls of the tympanic cavity, etc. Such infection, when it occurs, generally arises as the result of ignorant interference (*e.g.*, the instillation of irritating oils and other solutions). The injury caused by sudden changes in air pressure (condensation or rarefaction) is more apt to occur in individuals in whom there is a stenosis of the Eustachian tube.

In simple rupture of the membrana tympani it is sufficient to introduce a little protective cotton or gauze into the canal and allow nature a chance to repair the injury. Neither irrigation nor inflations should be used. In complicated cases (with hemorrhage from the ear and injury of the labyrinth) absolute rest and quiet should be insisted upon. Potassium iodide and muriate of pilocarpine should be pushed to their physiological limits, for the purpose of hastening absorption of the exudate. Other complications will have to be met according to their nature.

Fracture of the Malleus.—Fracture of the handle of the malleus has resulted from a blow upon the ear, from a fall on the head, and through direct injury inflicted by a foreign body. The fragments may unite (with the formation of a callus) at an obtuse angle to each other, or union may fail to take place, as in the case reported by Weir.*

IV. MIDDLE EAR.

The middle ear is the seat of the largest number of ailments which come under the aurist's care, and in special treatises devoted to diseases of the ear these various ailments receive full consideration. It is not the purpose of the present writer, however, to occupy the limited space assigned to this subject, with descriptions of all the different disorders to which the middle ear is liable, but rather to confine his attention largely to a consideration of those particular pathological processes which call for therapeutic interference of a surgical nature, and to a description of the operations which have for their object the relief of these disorders and the prevention of those very serious complications which in past years have so frequently terminated in the death of the patient.

Acute Catarrhal Inflammation of the Middle Ear.—Acute catarrhal otitis is frequently met with as a complication of a coryza, a pharyngitis, or a tonsillitis, or as the result of direct infection carried by the forcible entrance of water into the middle ear (by way of the Eustachian tube) during diving or washing out the nares or naso-pharynx. Exposure to cold is another etiological factor,

* Weir: "A Case of Ununited Fracture of the Malleus." Medical Record, New York, 1871.

as is also vomiting with regurgitation into the naso-pharynx. Or the inflammation may arise as the result of the mere presence of hypertrophied pharyngeal or faucial tonsils, of hypertrophy of the nasal mucous membrane, or of an ethmoiditis, sphenoiditis, etc.

Symptoms.—The symptoms commonly experienced are: a dull pain in the ear, tinnitus, and a feeling of fulness in the ear. There is generally some elevation of temperature. The drum membrane is reddened and swollen, and at times there is bulging, particularly of the posterior half. If the infiltration of the membrane is not so marked as to cause it to lose its translucency, fluid may be seen behind it. This fluid can easily be recognized when the patient moves his head backward and forward and thus causes the fluid to change its level.

Treatment.—The drum membrane should be incised early if there is any bulging outward of its surface. The incision should be preceded by an aseptic cleansing of the canal and followed by aseptic drainage.

Acute Purulent Inflammation of the Middle Ear.—This is an inflammation of the mucous membrane of the tympanic cavity, with perforation of the drum membrane and a discharge of an inflammatory exudate.

Etiology.—The inflammation is brought about by the entrance of an infective micro-organism into the tympanic cavity. The micro-organisms most frequently met with are the streptococci, staphylococci, pneumococci, the Bacillus meningitidis capsulatus, the Bacillus pyocyaneus, etc. They usually make their way from some focus of acute inflammation in the nares, the naso-pharynx, the pharyngeal or the faucial tonsils, the ethmoid cells, etc., and this focal inflammation is often associated with one of the exanthemata, with the grippe, with diphtheria, etc. The infection may also develop in consequence of the introduction of septic material into the Eustachian tube through the improper use of the nasal douche or after bathing and especially diving. The infection produced by scarlet fever is much more virulent than that which comes from measles, but it does not occur so frequently. Children are more often affected than adults because of their tendency to enlarged pharyngeal and faucial tonsils and because they are more subject to coryzas and the exanthemata. The lowering of the resistance always makes the patient much more susceptible to an extension of the nasal or naso-pharyngeal inflammation to the tympanic cavity.

Symptoms.—The symptoms characterizing this disease are the following:—Elevated temperature (in infants, often as high as 105° F.); pain, of variable degrees of severity, sometimes absent altogether; difficulty in hearing, slight at first, but gradually becoming more marked; tinnitus; headache, and a general feeling of malaise. The external auditory canal is frequently stenosed, especially at the inner end. If the epitympanic space or the mastoid antrum is involved, there is a drooping of the skin covering the posterior superior wall. The drum membrane is reddened, swollen, and infiltrated; all its landmarks are obliterated. If spontaneous perforation occurs, the opening is very apt to be nipple-shaped. The secretion may be serous, partly serous and partly mucoid, sero-sanguineous, muco-purulent or sero-purulent, in character. In favorable cases the discharge does not last longer than from a few days to a few weeks. Pain does not recur, the hearing is not markedly involved, and the drum membrane rapidly resumes its normal appearance. On the other hand, in unfavorable cases infiltration of the drum membrane becomes very marked, and the edges of the perforation undergo thickening and tend to coalesce, thus preventing proper drainage. The mucous membrane in the tympanic cavity is also swollen and œdematous, and in certain cases the swelling shows a tendency to localize itself in such a manner as to shut off the lower portion of the tympanic cavity from the upper portion and thus obstruct the drainage from the epitympanic space. This will explain why in some cases the mastoid antrum and the cells communicating with it become involved. Tenderness over the mastoid process is especially apt to be found over the tip. Tenderness at this point is practically always present in cases of acute purulent middle-ear infection, and is less diagnostic of mastoid involvement than when tenderness is to be found over the mastoid antrum or over the exit of the mastoid emissary vein. Where the virulency of the disease is not marked, the case terminates favorably without the production of any permanent deafness or of any lesions worthy of note. (The course of the disease in the more serious cases is described further on.)

Treatment.—The external auditory canal should be thoroughly cleansed, and an early incision made in the drum membrane. The discharge from the tympanic cavity should be drained away as fast as secreted. The canal should be irrigated at regular intervals, the number of irrigations to be determined according to the amount and character of the discharge. For this purpose either sterile water or a saline or mildly antiseptic solution should be used. As a rule, irrigations are used more frequently than is necessary. The better plan is to introduce into the canal, as far as the drum membrane, a simple narrow strip of sterile gauze, and to substitute a fresh strip as often as it becomes partially saturated—every fifteen, twenty, or thirty minutes, according to the activity of the discharge. The bowels should be evacuated early by means of calomel and a saline purge. If pain is severe, codeia or morphia may be used at the very beginning of the disease, but should not be continued for more than a few days, as it might otherwise conceal symptoms of mastoiditis.

In cases where mastoid tenderness is present, the ice coil might be tried for not longer than thirty-six hours. Heat is equally effective, is free from the danger of masking symptoms of mastoiditis, and may be continued for a number of days. Argyrol in twenty- to thirty-per-cent solutions may be instilled into the tympanic cavity with beneficial results.

After the inflammation has subsided, treatment will have to be directed toward the improvement of the hearing and toward the prevention of the formation of adhesive bands in the tympanic cavity. To accomplish this purpose, inflation by means of the Politzer bag or by means of the Eustachian catheter will have to be instituted three or four times a week for a number of weeks. It is under circumstances like these that pneumatic massage of the drum membrane may be employed to great advantage. It seems scarcely necessary to add that the general health should be attended to.

Myringotomy.—Myringotomy should be performed in all cases where there is any redness associated with even very slight bulging of the drum membrane, and especially if it be accompanied by pain. Before the incision is made, the canal should be thoroughly cleansed and rendered as aseptic as is possible. The incision should not be a mere slit-like opening a few millimetres in length, but should be sufficiently long to allow for ample drainage. (Fig. 342.) No baneful effects have ever resulted from a free incision, as its edges readily unite—indeed, often before it is desirable that they should do so. The incision should be made so as to extend from the junction of the anterior superior quadrant with the anterior inferior quadrant in a curved direction (following as closely as possible the tympanic margin), downward, backward, and then upward as far as the posterior ligament. The incision is best made with a slender knife. The point of the knife should not pass deep enough into the tympanic cavity to wound the mucous membrane of the promontory of the middle ear. As the depth of this cavity is only 2 or 3 mm., the knife should not pass into it much beyond the inner surface of the drum membrane. The wounding of the mucous membrane of the inner wall of the tympanum gives rise to bleeding and adds to the amount of fluid which has to escape from the tympanic cavity through the opening in the drum membrane into the external auditory canal. This blood may also clot in the tympanic cavity and act as an obstruction to the free escape of the inflammatory exudate through the artificial opening. In making the incision in the drum membrane, it should be remembered that the jugular bulb lies immediately beneath the floor of the tympanic cavity and that in a few cases there is a dehiscence of this floor. It is therefore possible that the knife may pass into and wound the vein. If such an accident should happen, the drum membrane should at once be thoroughly opened and the tympanic cavity packed tightly with sterile or iodoform gauze. The danger from hemorrhage, in such an accident, is slight; a graver danger lies in the possible infection of the bulb of the jugular vein. Furthermore, care should be taken, in making this incision in the drum membrane, not to injure the incudo-stapedial joint.

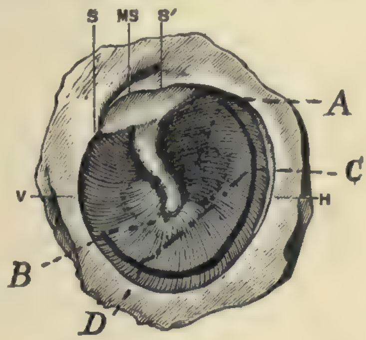


FIG. 342.—External View of the Tympanic Membrane, to show the line of incision in a myringotomy. (After Politzer, with modifications.) The heavy black line, which runs parallel with the periphery of the membrane from *A* to *B*, represents the course of the incision. The dotted line *AB* shows where the hinge of the flap is located. From these data one may judge how perfect is the drainage which such an incision affords. In marked contrast with it is the limited drainage that can be obtained by the incision from *C* to *D*.

V, Segment of the tympanic membrane lying in front of the handle of the malleus; *H*, posterior segment of the tympanic membrane; *S*, *S'*, Prussak's striæ, passing from the short process of the malleus to the spina tymp. post. et minor; *MS*, Shrapnell's membrane.

Where there is reason to believe that the epitympanic space or the mastoid antrum is involved,—as indicated by drooping of the upper posterior cutaneous wall of the external auditory canal,—the incision in the membrane should be carried upward upon the wall of the external auditory canal and thence outward through this drooping tissue.

After-treatment.—The patient should always be kept in bed as long as there is the slightest elevation of temperature or as long as there are other evidences indicating the possible involvement of the mastoid process. The bowels should be thoroughly evacuated, preferably by means of a calomel-and-saline purge. The external auditory canal should be kept free of all exudate in the manner described on page 688. It is bad practice to insufflate boric-acid or any other powder into the external auditory canal, as it is impossible that the powder, when thus introduced, should exert any germicidal action upon the contents of the tympanic cavity. By mixing with the discharge, however, and becoming caked, it may cover the opening in the drum membrane and so act as an obstructive dam.

In cases where the inflammatory exudate causes a marked thickening of the drum membrane, a simple myringotomy may fail to afford adequate drainage from the middle ear. When this is the case, an attempt should be made to establish an opening in the lower portion of the drum membrane. This may be done by means of the blunt-pointed knife, or more easily still by using Hartmann's middle-ear cutting forceps.

Cases that do not get well as promptly as they should, and that show a tendency to form new tissue, often begin to improve when argyrol (twenty- to thirty-per-cent solutions) is either instilled into the tympanic cavity through the perforation in the drum membrane or blown into the middle ear by way of the Eustachian tube. When the remedy acts in this favorable manner its use should be continued regularly.

Acute Inflammation of the Mastoid Process.—ETIOLOGY AND PATHOLOGY.—Acute inflammation of the mastoid process represents an extension of a middle-ear inflammation to the antrum and the mastoid cells. In acute otitis media the more violent the primary infection of the nasal or naso-pharyngeal mucous membrane, the greater the likelihood of extension from the tympanic cavity to the mastoid antrum and the other mastoid cells; and especially is this true if drainage of the inflammatory products from the middle ear is not early and sufficiently well provided for.

In acute inflammation of the middle ear an early and a free incision of the drum membrane often saves the patient a much more serious operation. It is probable that in almost all cases of acute purulent middle-ear infection the aditus ad antrum and the mastoid antrum are involved. If this were not so it would be difficult otherwise to account for the amount of discharge that is generally found to be present in these cases, an amount so abundant as to be out of all proportion to the small secreting surface of the tympanic mucous membrane. The aditus ad antrum, or the passage leading from the tympanic cavity into the mastoid antrum, is very short, and, if drainage from the tympanic cavity is not quickly established, the mucous membrane in this narrow passage quickly becomes so swollen as to obstruct the drainage from the mastoid antrum. As a consequence, the products of inflammation pass backward and downward into the other cells of the mastoid process. In a certain number of cases, if the inflammation is not of a particularly virulent type, those products in the mastoid cells may be absorbed, and recovery may take place without any further manifestation of the disease. Bezold states that in nine per cent of all cases of acute purulent middle-ear infection, the mastoid cells are involved to so serious an extent that spontaneous recovery is no longer possible.

Primary mastoiditis is extremely rare. Out of over one thousand cases of mastoiditis operated upon by the writer there were only two (not of traumatic origin) in which the evidence warranted the belief that the mastoid cells had been primarily involved. It occasionally happens that, after the almost complete subsidence of the primary inflammation in the tympanic cavity,—the perforation having healed and the membrane itself having nearly regained its normal appearance,—an acute mastoiditis develops. Such a case, however, cannot rightly be considered one of primary mastoiditis; the inflammation is due rather to a lighting up of some retained portions of infective material in the mastoid cells.

Measles, scarlet fever, and *la grippe* are responsible for the largest number of cases of inflammation of the mastoid process, and these diseases are especially likely to induce this inflammation when hypertrophy of the pharyngeal tonsils coexists. Mastoid inflammation may also occur as a complication of diphtheria, typhoid fever, pneumonia, and diabetes mellitus, but such cases are relatively rare. In a general way it may be said that the etiology of mastoid inflammation is the same as that of all acute inflammations of the middle ear.

Symptoms.—The prostration dependent upon the original infective cause is at times increased, but, as a rule, there is no great prostration even in marked cases of simple uncomplicated mastoiditis. The purulent discharge is usually more marked than when the disease is confined to the tympanic cavity, and yet, in not a few cases, there is an absence of all discharge. Pain in the deeper parts of the ear may be severe; seldom is it entirely absent. Tenderness on pressure may be found over the tip, over the mastoid antrum, over the point of exit of the mastoid emissary vein, or over the entire mastoid process. There are often cases, however,—some of them of the most serious type,—in which not the slightest tenderness can be elicited by pressure. Except in children and in complicated cases the temperature very seldom rises above the point where it stood for the original disease. Œdema of the tissues over the mastoid process may be indicative either of a mastoiditis or of a circumscribed inflammation of the external auditory canal. The distinguishing features of the two diseases are the following:—*In mastoiditis* there is generally a previous history of some nasal or naso-pharyngeal disease; acute pain in the ear develops rather suddenly and the pain is associated with deafness; generally a discharge is present; tenderness is obtained when pressure is exerted directly over the bone; manipulation of the auricle is generally painless; an examination of the canal seldom reveals any narrowing of its lumen, but the membrana tympani is seen to be congested and bulging, the bulging being especially marked in the superior posterior quadrant; if a perforation exists, as it generally does, a pulsating discharge exudes from it; all landmarks of the membrana tympani are obliterated. *In furunculosis* there is no discharge; the canal is stenosed; a very limited view of the drum membrane, or no view whatever, is obtainable, and if the membrane can be seen it will be found to present a normal or very nearly normal appearance; manipulation of the auricle is painful, and, according to the location of the furuncle, tenderness will be found to be present by pressing from behind forward, from before backward, from above downward, or from below upward upon the wall of the external auditory canal; exquisitely tender spots will be found to be present in the canal on making pressure with a cotton-tipped applicator or probe over the seat of the swelling; often the hearing, if affected at all, is only slightly impaired.

Œdema of the mastoid integuments develops early in cases of mastoiditis only when the infection is very violent; when it develops at a later stage it will usually be in a case in which the disease has been allowed to progress too far before operative interference is resorted to, or in one in which a subperiosteal abscess is found to be present.

TREATMENT.—As stated on a previous page, the best way of preventing or aborting a mastoiditis is to make an early and extensive opening in the drum membrane, especially in its upper and posterior segment, to allow of free drainage. To carry off the discharge as rapidly as possible, a gauze drain should be used in the external auditory canal, and changed as frequently as is necessary to keep the canal free of discharge. It may be necessary to change the gauze every fifteen or twenty minutes. The use of hot-water irrigations is sometimes necessary, but, as already stated, they are used too frequently. If cold is applied to the mastoid process it is best not to continue its use for over thirty-six hours, as it tends to mask the symptoms and thus easily to lure the surgeon into the belief that all is well when the reverse is true. The use of opiates, except in the beginning, is unwise. All such measures as blistering and leeching should be avoided as unsurgical and more likely to do harm than good.

The patient should be kept in bed and very quiet. In the beginning a grain of calomel should be given (in one-tenth-grain doses every half-hour), and a saline should be administered the next morning. The diet should be light and of a quality that may be easily digested.

If, despite these measures, the disease continues to advance, an operation is imperative. As to how long one should wait before operating is a question that has to be decided by the symptoms in each individual case. I have seen cases get well when all the symptoms seemed to urge an immediate operation; but the danger to life of delay in such cases is great, and in the long run the surgeon who operates when the symptoms undoubtedly call for it, will have the smallest number of fatalities. I cannot recall a single case in which, when the mastoid was opened, I failed to find the conditions such as entirely justified operative interference.

Mastoiditis in Diabetic Subjects.—A mastoid inflammation in a person affected with diabetes mellitus generally results fatally. Some operators give a death-rate as high as one hundred per cent. At the onset of the middle-ear infection, free drainage of the tympanic cavity should at once be established and maintained. In this connection the following case history is of interest:—

The patient, a man 50 years of age, with three and one-half per cent of sugar in the urine, was seen by me during the second week of an attack of purulent otitis media. The external auditory canal was stenosed, there was drooping of the posterior superior canal wall, a profuse discharge was present, and there was slight tenderness over the mastoid process. The patient had been advised by three specialists to have the mastoid cells opened, but, because of the presence of diabetes, his family physician would not consent. A myringotomy had been performed three times, and yet the drum membrane was still very œdematous and bulging, and the opening in it was very small. Under chloroform anæsthesia I performed a fourth myringotomy. Two days later, as no improvement had taken place in the appearance of the drum membrane, I removed (under chloroform anæsthesia) a large section (about two-thirds) of the posterior half of the tympanic membrane by means of Hartmann's cutting forceps.

Four days later, a decided improvement had taken place. In three weeks' time the discharge had ceased, the drum membrane had healed, and the patient was discharged cured. Although injections of a twenty-per-cent solution of argyrol formed a part of the treatment, I am disposed to believe that the establishment of adequate drainage was by far the most potent factor in the resultant cure.

Chloroform should be selected as the anæsthetic to be used in these cases. Proper diet should be enforced. The use of codeine in increasing doses has been found of benefit. Dyspnœa is a very dangerous symptom. The mastoid operation should be done as rapidly as possible and the bone should be removed beyond the diseased area. In order to secure the maximum degree of drainage the wound should be left open and no sutures should be employed.

V. THE MASTOID OPERATION AS APPLIED TO CASES OF ACUTE MASTOIDITIS.

Indications for Opening the Mastoid Cells.—In many cases there is no single symptom, local or general, which, considered by itself, will lead the surgeon to say positively that the mastoid cells ought to be explored. The decision to operate is reached in most cases by a careful consideration both of the history of the case and of the actual conditions revealed by the examination of the ear and of the surrounding tissues. When the facilities for making a bacteriological examination are within reach, valuable aid may be derived from this source in determining what kind or kinds of micro-organisms are instrumental in perpetuating the local inflammation. For example, if such a bacteriological examination reveals the fact that the Bacillus mucosus capsulatus is present in the discharge which comes directly from the middle ear,* the surgeon will be disposed to urge the importance of operating with as little delay as possible, for experience has demonstrated that this germ causes a rapid breaking down of

* Special care is necessary in obtaining the material for bacteriological examination, as one may very easily contaminate it by contact with the germ life that is constantly present in the external auditory canal.

all structures which it attacks, and yet at the same time produces little or no attendant physical signs indicative of the damage that is being done. The Streptococcus meningitidis is another organism which is capable of causing marked destruction of the tissues in a very short time; and, in cases where this germ is found, unless positive evidences of improvement have already appeared, an early operation is advisable. Cases in which a pure streptococcus infection exists come to operation in over fifty per cent of the total number; and, if decided improvement does not take place within a week, it is best in these cases to operate without any further waiting, even if the other physical signs of mastoiditis are lacking. It is estimated that over sixty per cent of the cases in which the pneumococcus is found to be present recover without operative interference so far as the mastoid is concerned; and in probably not more than fifteen per cent of the cases in which the staphylococcus is the infective agent, is it found necessary to open the mastoid cells.

The most constant and the most trustworthy symptoms of the purulent involvement of the mastoid process are *a profuse discharge of creamy pus from the middle ear and a simultaneous prolapse of the posterior and superior cutaneous wall of the external auditory canal near the drum membrane.* But there may be serious involvement of the mastoid cells even when these associated symptoms are entirely absent. In some cases there may be no pain in the region of the ear and no tenderness when pressure is made over the mastoid process. From time to time there have been reported cases of pronounced mastoiditis in which, at no time during the progress of the disease, was there any evidence of inflammation of the tympanic membrane.

A very frequent and very prominent symptom is tenderness on pressure over the whole or a portion of the mastoid process. The tip is the most frequent site of this tenderness, and the area over the antrum comes next. When the tenderness is most marked over the posterior cells of the mastoid process it is quite possible that we are dealing with a case complicated either with a perisinous abscess or with a sinus thrombosis. Another point where the mastoid tenderness is to be detected is the posterior surface of the wall of the external auditory canal. If the case is a recent one, tenderness on pressure at this point may not be very significant; but if it persists, without diminution in intensity, for forty-eight hours, then it is time for the surgeon to invade the mastoid cells. The difficulty is, that this symptom of mastoid tenderness on pressure is, as I have already stated, frequently absent even in a case of well-marked mastoiditis.

In using pressure as a means of detecting mastoid tenderness it is important that this pressure should be firm and steady. It is also advisable to test both mastoids,—the presumably healthy one as well as the suspected one,—as in some individuals hyperæsthesia is marked, and one may find as much tenderness on pressure over the healthy mastoid as over that which appears to be involved.

Pain which is located in the mastoid process or its vicinity, and which persists despite free drainage, is another diagnostic symptom of mastoiditis. Still another is to be found in hyperæmia and œdema of the skin covering the mastoid process. When these conditions are found in a case in which furuncular inflammation of the external auditory canal is not present, it is time, in the vast majority of instances, to operate. The only possible exception is in those cases in which this symptom manifests itself very early in the disease (the second or third day), when a delay of from twenty-four to thirty-six hours is permissible, provided no other symptoms of mastoiditis are present. As a rule, however, hyperæmia and œdema develop at a relatively late stage of the disease, and when they are present at an early stage of the disease the signification generally is that the case has progressed very rapidly, or that the mastoid cortex is quite thin.

Extension of the inflammation into the soft parts of the neck generally means that a perforation through the inner table has taken place. It may also signify a similar perforation through an unusually thin bony wall of one of the large cells at the tip of the mastoid process. Cases of mastoid fistula demand immediate operation.

Torticollis occurring in cases of aural disease is suggestive of a mastoiditis with spontaneous perforation of the inner plate of the mastoid process and a burrowing of the pus into the muscles of the neck. It may occur, however, in lymphatic children because of the involvement of the lymphatics in this region in cases where there is only a mild otogenic infection.

If the body temperature remains high for four or five days or is of a septic type, the operation ought not to be delayed.

Finally, it must be remembered that there are cases of well-developed mastoiditis in which all of the symptoms mentioned above may be absent.

A good rule to follow, in all cases where the mastoid infection is not well defined, is—when in doubt as to the necessity of an operation, take the less dangerous course and explore the mastoid process; never wait for redness and swelling or fluctuation over the mastoid.

Preparation of the Patient.—If the exigencies of the situation are such that from twelve to eighteen hours may be allowed to elapse before the operation, the patient should be prepared as for any other major operation. The bowels should be thoroughly evacuated, the healthfulness of heart, lungs, and kidneys ascertained, and the patient should be without any food in the stomach for a period of at least six hours before the administration of the anæsthetic.

The hair over a considerable extent of the head in the vicinity of the mastoid process should be shaved, and the underlying skin surface, as also the auricle, should be rendered aseptic by cleansing with tincture of green soap and warm water, alcohol, and a 1:1,000 bichloride-of-mercury solution, and then covered with a moist bichloride-of-mercury (1:3,000) dressing. If a complicating brain abscess is suspected, the entire head should be shaved.

The external auditory canal—which is, as a rule, serving as a drain for the pus flowing from the tympanic cavity—should be irrigated with a bichloride-of-mercury solution (1:3,000) sufficiently often, during the interval between the application of the moist dressing and the time of operation, to keep it fairly free of pus. After each irrigation a wick of sterile gauze should be inserted into the canal, and a fresh external dressing applied.

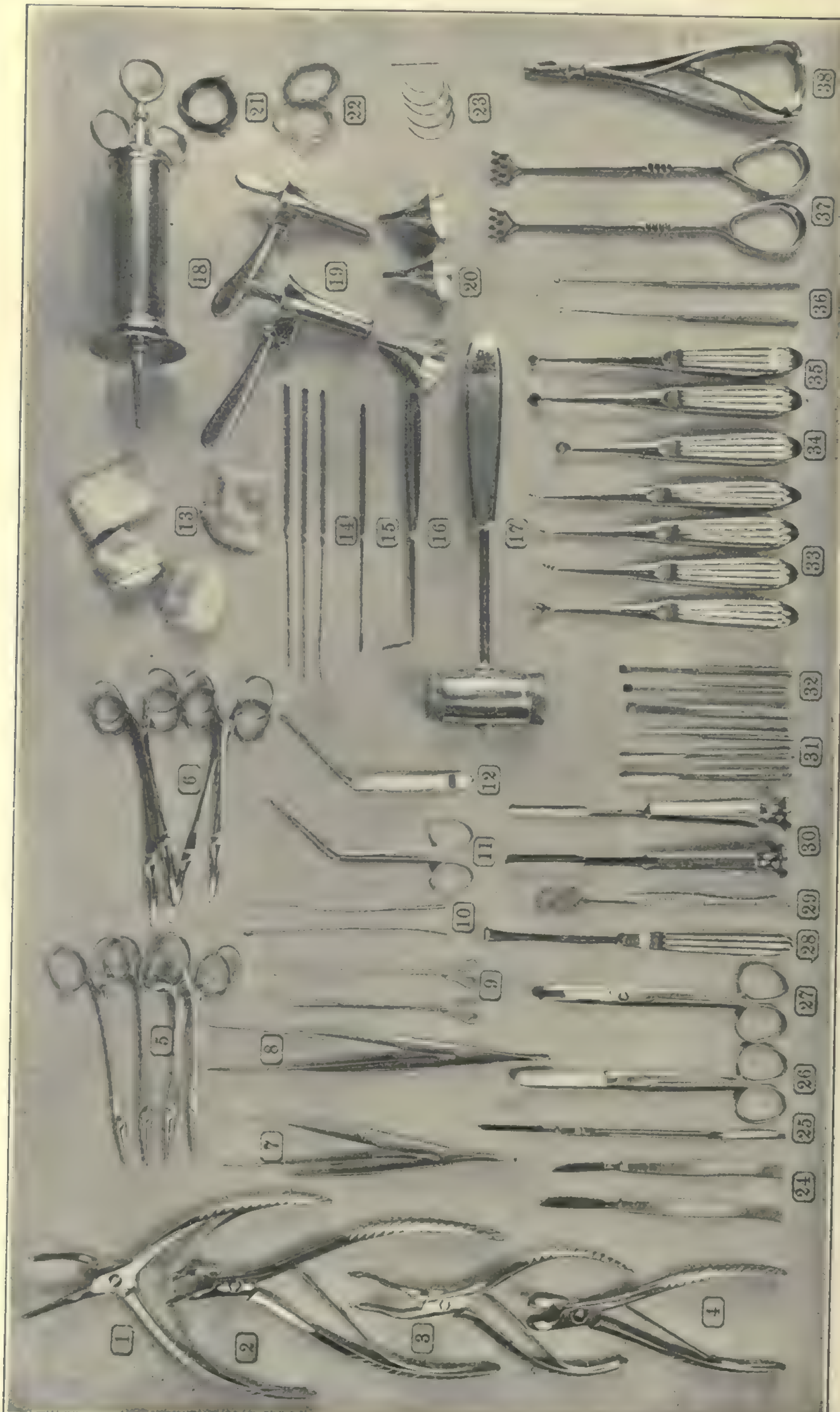


FIG. 343.—Instruments Required in Operations upon the Mastoid Process.

In many cases the necessity for immediate operation will not permit the making of the preparations just described. In all cases, however, the patient, the surgeon, and his various assistants, as well as everything that may directly or indirectly come in contact with the wound, should be rendered as thoroughly aseptic as possible.

The patient should be placed upon the operating-table with a hard cylindrical pillow under his head. (This pillow, however, should be of the same thickness as the other cushions which cover the table, as it is not desirable that the head should be elevated above the level of the shoulders.) A piece of India-rubber sheeting, large enough to extend well over the shoulders and chest of the patient and below the cushions of the table, should be securely fastened about his neck. Two sterile towels are placed under the head while it is held suspended by an assistant, who at the same time cuts the bandage holding the previously applied dressings in place; one towel covers the pillow, and the other is fastened tightly around the patient's head so as to leave exposed only the shaved portion of the field of operation; four other folded sterile towels are securely fastened to this and to one another as well as to sterile towels which cover the rubber sheeting, and completely cover face, neck, and head, leaving exposed only the quadrangular field for operation.

The Instruments Needed.—It matters not how simple the case of mastoiditis about to be operated upon may appear, the surgeon should at all times be prepared, if such a step should be found necessary, to open the sinus and excise the jugular vein for a sinus thrombosis, or to open the skull and explore the brain for a cerebral or a cerebellar abscess. He should have for the operation the following instruments (Fig. 343):—

Whiting's long-beaked bone forceps (1)* for working in the bottom of such deep-seated cavities as those which lie above the jugular bulb, in the petrous cells, or in the narrow space between the tip cells and the antrum, where the sigmoid groove lies far forward, or in the space between the upper border of the sigmoid groove and the floor of the cerebral cavity and the posterior boundary of the antrum; Whiting's short-beaked forceps (2) for working in narrow but shallow cavities; Jansen's forceps (3) for the removal of the posterior and upper wall of the external auditory canal between its external surface and the exposed anterior boundary of the antrum and aditus ad antrum, thus making one cavity of the middle ear, and external auditory canal—the forceps is so fashioned that the desired plate of bone may readily be removed without at the same time wounding the facial canal; Mathieu's forceps (4) for rapid work in removing large pieces of bone; straight and curved hæmostatic clamps (5); mouse-toothed dressing forceps (6); blunt dressing forceps (7 and 8); grooved directors (9); silver probes (10); Hartmann's ear forceps (11); Politzer's ear forceps (12); gauze (iodoform and plain sterile) strips one inch wide (13); cotton applicators (14); myringotome (15); aneurism needle (16); mallet (17); Pomeroy's aural syringe (18); Whiting's encephaloscopes, large and small (19); aural specula, Boucheron's (20); silkworm gut for sutures (21); catgut for sutures and ligatures (22); needles (23);

* These numbers (1 to 38) refer to the individual instruments shown in Fig. 343.

scalpels (24); probe-pointed bistoury with extra long blade for making meatal flap in the radical mastoid operation (25); scissors, straight (26); scissors, curved on the flat (27); periosteal elevator, Langenbeck's (28); periosteal elevator (29); bone gouges, large (30); gouges, small (31); chisels (32); bone curettes, Buck's (33); bone curette, fenestrated (34); bone curettes, fenestrated, Richard's, for working chiefly with the handle at or nearly at a right angle to the bone and toward the operator (35); Buck's sharp ring curettes for working in the tympanic cavity (36); retractors (37); needle holder (38).

It adds materially to the expeditiousness of the operation if the surgeon has some definite arrangement for placing the instruments on the table. After a short time he is able without hesitancy to place his hand directly on the instrument wanted. (Fig. 343 shows the table in a measure so arranged.) The instruments enumerated above and shown in the figure are not required for every operation. For the simple mastoid operation many of them are superfluous. The instrument table is larger than the one shown here, and the space occupied by the syringe, gauze, cotton-carriers, encephaloscopes, and catgut is used for a tray of sterile water where the instruments are cleansed of blood as rapidly as put aside by the surgeon and again put in their designated places on the table. An infusion apparatus, an irrigation bottle, needles, catgut for ligatures, silkworm gut for sutures, iodoform gauze in bulk as also in strips one-half inch and one inch wide (Nu gauze, with selvedge edge, as prepared by Johnson and Johnson, has the advantage of not unravelling), dry sterile gauze handkerchiefs and sterile cotton for dressings, bandages two inches wide, also dry sterile gauze sponges, should be provided.

Minor Operative Details.—Each surgeon will have his own preferences as to minor operative details. I prefer to stand at the head of the table, near its right-hand or left-hand side, according to whether it is the right or the left ear which is involved. The anæsthetist stands in front of the patient's everted face; the second assistant, who manages the retractors and holds the artery forceps out of the way, stands between the anæsthetist and the operator; while the first assistant, who sponges and seizes the bleeding vessels, stands on the other side of the operator. The instrument table with the attendant nurse is within convenient reach.

Narcosis.—My preference is for nitrous-oxide gas followed by ether. In cases of suspected brain abscess in very young children, in kidney complications, or when œdema of the lungs is to be feared, chloroform is to be preferred. Schiebe reports six cases in which local anæsthesia (ethyl chloride) was employed, in five of which cases it gave good satisfaction.

Drs. Marquis and Kraft (*Jour. Amer. Med. Assoc.*, April 22d, 1905) describe the following method of local anæsthesia in major and minor operations upon the ear. The patient is given a meal, as the cocaine is less toxic when administered after eating; he is prepared for the operation in the usual way. Three solutions are prepared:—

(*a*) One-per-cent solution of eucaine in distilled water, with five drops of adrenalin chloride solution (strength, 1:1,000) to each cubic centimetre of the solution.

FIG. 1.

FIG. 2.

EXPLANATION OF PLATE XXXVI

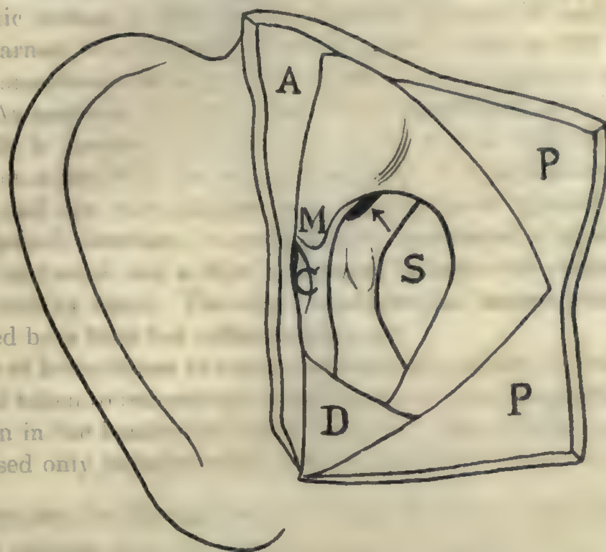


Fig. 1.—THE SIMPLE MASTOID OPERATION.

The auricle (left) is reflected forward, and the two triangular flaps backward. A, the anterior flap; P, P, the posterior flaps; S, the bone covering the sigmoid curve of the lateral sinus; D, the digastric muscle (the tip of the mastoid process having been removed, the exposed muscle comes outward into the wound); C, the posterior surface of the beginning of the bony external auditory canal; M, the supra-meatal spine, or spine of Henle (the supra-meatal fossa lies below the spine); the arrow points to the antrum.

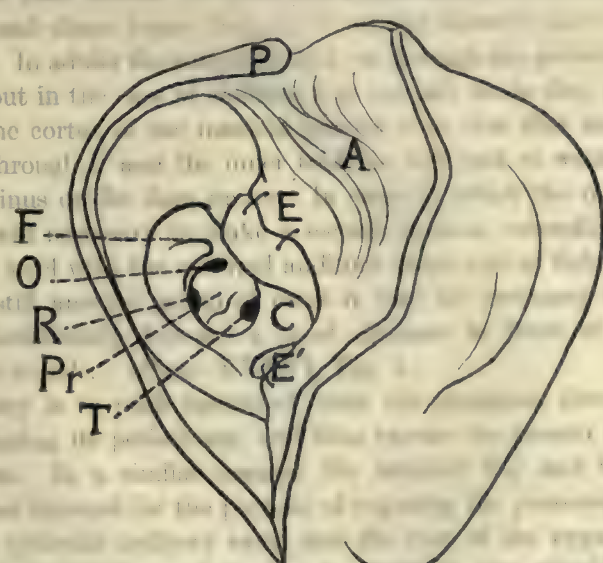
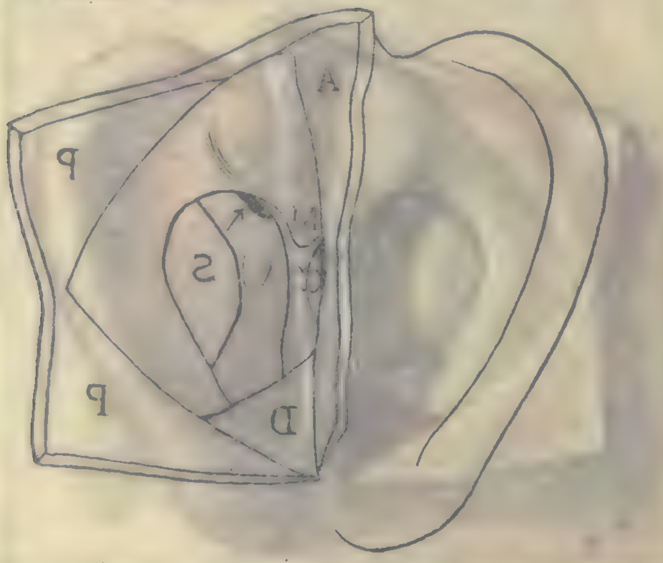


Fig. 2.—THE RADICAL MASTOID OPERATION.

The auricle (right), with all of the skin covering the mastoid process, is reflected forward. This constitutes the anterior flap A. P, the posterior flap; E, the meatal flap, made from the membranous lining of the external auditory canal, turned up and held in position by sutures; E′, the smaller inferior flap. Both flaps (E and E′) present their epithelial surfaces to the observer and should therefore not look so nearly like the periosteal surface of the anterior flap to which they are attached. F, the ridge of the facial canal; Pr, the promontory of the tympanum; R, the fenestra rotunda; O, the fenestra ovalis; T, the mouth of the Eustachian tube; C, the anterior wall of the external auditory canal.

EXPLANATION OF PLATE XXXVI



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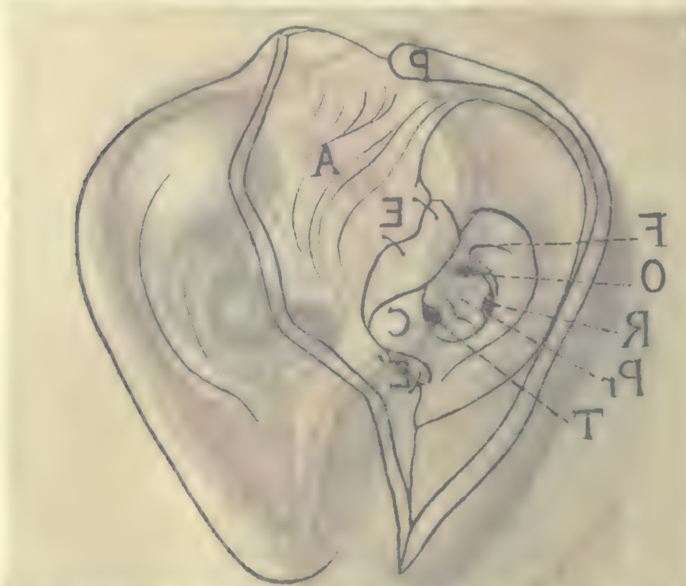

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(*b*) One-per-cent solution of cocaine in distilled water, with five drops of adrenalin to each cubic centimetre of the solution.

(*c*) Twenty-per-cent solution of cocaine.

The hypodermatic syringe is filled with the eucaine solution (*a*) and immersed in hot water until warmed to a temperature of 40° to 50° C. (104° to 122° F.). This is essential, as the anæsthesia develops more rapidly if the eucaine is injected at this temperature. An assistant takes the place of the anæsthetist, and watches the patient. The needle is inserted over the mastoid on a level with the external auditory canal and on a line with the intended incision; it is pushed onward until the bone is reached, and one cubic centimetre of the solution is injected under the periosteum in an upward direction. A second cubic centimetre is injected downward, inward, and backward, and a third is injected between the cartilage of the ear and the bony auditory canal. The slight headache and nausea which are apt to follow are relieved by a little hot coffee and brandy.

After the lapse of from fifteen to twenty minutes the patient is ready for the operation. If care is taken to remove only small pieces of bone the patient does not suffer any more than in the hands of a dental surgeon. This method, as a matter of course, will be used only in cases where general anæsthesia is contra-indicated.

As a preliminary step to the mastoid operation the drum membrane should be incised, if a free opening does not already exist in it, and a strip of iodoform or plain sterile gauze should be inserted into the auditory canal.

The Operation.—The first incision is made by inserting the point of the knife, held at right angles to the surface of the skin, over the tip of the mastoid process, and carrying it through the periosteum to the bone; the handle should then be lowered so that the curved edge of the blade does the cutting, and the incision itself should be carried in a direction parallel to the insertion of the auricle, and about 5 mm. from it, to a point directly above the external auditory canal. In adults the scalpel should cut through the periosteum with the first incision; but in the case of children it is not safe to do this, for the reason that in them the cortex of the mastoid process is so thin that the knife might possibly pass through it and the inner table as well and so wound the underlying sigmoid sinus or the dura mater. In cases in which the mastoid process is large, it be will necessary to make a second incision, extending horizontally backward on a level with the external auditory canal and at right angles to the first one. In still another group of cases it may be necessary to extend the first incision horizontally forward a short distance in front of the anterior insertion of the auricle. (Plate XXXVI, Fig. 1.)

The next step is to push backward, with the periosteal elevator, the posterior flap including its periosteum, and thus expose the greater portion of the mastoid process. In a similar manner the anterior flap and its periosteum are to be pushed forward for the purpose of exposing the posterior and superior borders of the external auditory canal and the root of the zygomatic process. In separating the periosteum from the bone, great care should be taken to avoid wounding the membranous wall of the external auditory canal. If wounded it may give rise to a permanent opening behind the auricle or to atresia of the canal.

These steps having been taken, it is necessary next to control all bleeding by means of hæmostatic clamps. When this has been accomplished, two retractors are introduced and so placed that one shall hold forward the anterior flap, while the other pulls backward the posterior flap. It is generally necessary at this point in the operation to extend, with the scissors, the first incision downward for a distance of about 8 to 10 mm. Then, with the blunt-pointed scissors, curved on the flat, the operator carefully separates the tendinous insertion of the sterno-cleido-mastoid muscle from the tip of the mastoid process. The point of the scissors is kept in close contact with the bone and the muscle is divided by small bites, so as to avoid wounding any of the vessels of the neck. The bony surface of the mastoid process having thus been fully exposed to view, the surgeon must take notice of the landmarks which are to guide him in his further operative procedures. First, the attention is directed to the supra-mastoid fossa, a shallow depression which lies just above the juncture of the posterior and superior margins of the external auditory canal. This fossa, in front of which is to be found a small spine (spina supra meatum, or the spine of Henle) presents a sieve-like appearance, due to the presence of several vascular foramina (the vascular zone, or, as it is called by some authors, the spongy spot). At times these vascular foramina dip down into the underlying cells, the lining mucous membrane of which comes almost in contact with the external periosteum, and they thus afford an easy passage for pus from these cells to the surface of the mastoid. A carious opening will occasionally be found at this spot. The antrum is situated exactly on the same horizontal and lateral planes as this fossa. From infancy to adult life its position changes. In infancy it is above the meatus, but from this period onward it gradually moves downward and backward in a circle concentric with the auditory meatus, until, in adult life, it is to be found immediately behind the suprameatal spine. In infancy the centre of the antrum is slightly above and behind this spine, but it then gradually passes downward and backward until at the age of ten it is directly back of the suprameatal spine. From this age onward the centre of the antrum passes backward until, in the young adult, it is located at a distance of about 5 mm. from the suprameatal spine. This fossa, therefore, is our most important guide to the antrum, as it is always present, whereas this is not true of the suprameatal

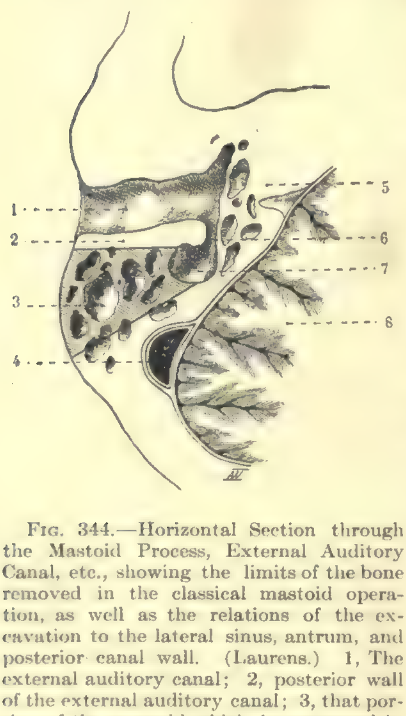

FIG. 344.—Horizontal Section through the Mastoid Process, External Auditory Canal, etc., showing the limits of the bone removed in the classical mastoid operation, as well as the relations of the excavation to the lateral sinus, antrum, and posterior canal wall. (Laurens.) 1, The external auditory canal; 2, posterior wall of the external auditory canal; 3, that portion of the mastoid which is excavated in the operative procedure; 4, sinus; 5, internal ear; 6, aditus ad antrum; 7, antrum; 8, brain. (The shaded area, 3, in the diagram is too narrow; it should extend far enough back to include the cellular structure lying outside the shaded portion.)

spine. Macewen's guide is a triangle, which he terms the "suprameatal triangle." This triangle is formed above by the posterior root of the zygomatic process, below by the superior and posterior wall of the bony external auditory canal, and behind by an imaginary line connecting the extremities of these two lines. In early life the non-existence of the posterior root of the zygomatic process renders this guide less positive than the one mentioned above.

The spine of Henle also gives some little idea as to the positions of the lateral sinus and middle cranial fossa. If the spine is high up in the meatal wall the surgeon may expect to find a sinus situated well forward and a low-lying middle cranial fossa.

The next landmark to observe is the linea temporalis, which is the extension backward of the posterior root of the zygomatic process. This is an important guide, as it indicates, in a fairly accurate manner, the level of the floor of the middle cerebral fossa, the latter being more often a little below than a little above this line. In broad skulls the middle fossa will generally be found lower than in long skulls.

Before beginning the operation the surgeon will do well to call to mind the anatomical structures which are to be avoided. The floor of the middle cranial fossa is, as I have stated above, quite easily avoided by not removing any bone—and especially so near the cortex of the mastoid process—above the line of the temporal ridge. Another very important structure which should be borne in mind is the lateral sinus. This structure (see Figs. 344, 345, and 346) is very variable in its relation to the mastoid antrum. According to Lake (*Journal of Laryngology, Rhinology, and Otology,* Vol. 13, p. 231), its distance from the antrum varies from 0.2 inch (5 mm.) to 0.7 inch (about 17 mm.). On an average it is situated at a distance of 0.48 inch (12 mm.) from this cavity. The sinus is more superficially situated than the antrum. On the right side it extends, as a rule, farther forward than it does on the left side, and in broad skulls it will generally be found located farther forward than in long skulls. The location of the sinus may be mapped out to a large extent by noting the area of greatest convexity of the mastoid process. The sinus will be found beneath this area.

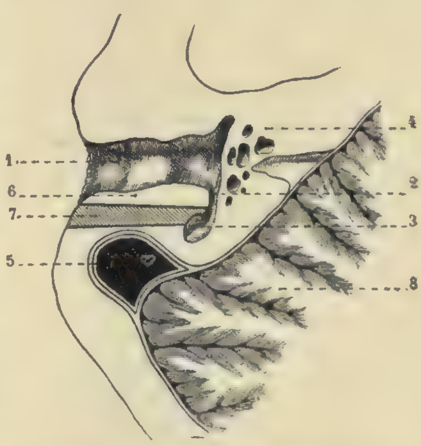

FIG. 345.—This diagram represents a horizontal section through the mastoid process, antrum, sinus, etc. In the picture the lateral sinus is situated very far forward, and the mastoid process is small and sclerosed. (Laurens.) 1, External auditory canal; 2, aditus ad antrum; 3, antrum; 4, labyrinth; 5, sinus; 6, posterior wall of the external auditory canal; 7, route by which the antrum may be entered; 8, brain. (Of course the excavated portion may be extended farther backward underneath the sinus.)

In infancy the distance of the antrum from the cortex of the mastoid process varies from 2 to 4 mm. ($\frac{1}{12}$ to $\frac{1}{6}$ inch), in children it has been found at as great a depth as 10 mm. ($\frac{2}{5}$ inch). In adults, on the other hand, it is farther removed from the surface of the bone, the distance (measured from the suprameatal fossa to the outer wall of the antrum) being from 12 to 18 mm. ($\frac{1}{2}$ to $\frac{4}{5}$ inch). Kerrison (*Archives of Otology*, Vol. XXXII., No. 3), by the measurement of a number of temporal bones, concludes that the depth at which the antrum is situated is always less, by actual measurement, than the length of the posterior superior canal wall, and that this depth rarely exceeds 15 mm., or about $\frac{5}{8}$ of an inch. (The average of all his measurements was 11 mm. [not quite $\frac{1}{2}$ inch], while the average length of the posterior superior canal wall was found by him to be 14.7 mm.)

When the surgeon encounters a case in which the antrum is located at an unusual depth, he must persist in his efforts to reach his objective point, but at the same time he must proceed with caution. In pneumatic mastoids this is comparatively an easy thing to do, but in individuals in whose ears chronic disorders have produced conditions of sclerosis, rendering it necessary to chisel through a hard, compact mass of bone, the difficulties are much greater; and to proceed requires the determination which comes alone with experience and from the knowledge that the antrum does exist and is to be found. The antrum is connected with the tympanic cavity by a canal—the aditus ad antrum; this canal is from 3 to 5 mm. ($\frac{1}{8}$ to $\frac{1}{5}$ inch) long, 3 mm. ($\frac{1}{8}$ inch) high, and 3 or 4 mm. deep. Its upper wall, the tegmen tympani, forms part of the thin plate which separates the tympanic cavity from the cranial cavity; at times it is wanting. The mucous membrane and endosteum lining the tympanum are in close contact with the underlying bone, and hence, in purulent inflammations of the tympanum, caries and necrosis readily occur. In view of the fact that the tegmen tympani and the tegmen antri are very thin, or may even be wanting, it is a source of wonder that abscess of the middle lobe or of the posterior portions of the temporo-sphenoidal lobe does not more often occur.

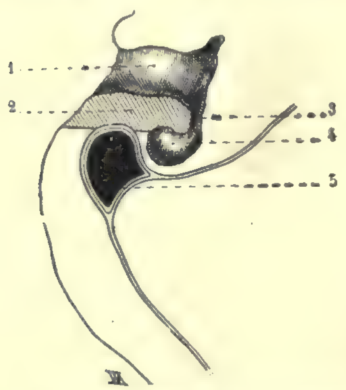

FIG. 346.—Horizontal Section (Diagrammatic) through the Mastoid Process, External Auditory Canal, Antrum, Sinus, etc. In the picture the sinus is situated very far forward, in front of the antrum. In a case like this it would scarcely be possible to reach the antrum except by removing the external portion of the posterior wall of the external auditory canal. (Laurens.) 1, External auditory canal; 2, posterior wall of the external auditory canal removed in the search for the antrum; 3, aditus ad antrum; 4, antrum; 5, sinus.

Two very important structures, it should be remembered, are in close relation to the aditus ad antrum, namely the facial nerve and the horizontal semicircular canal, which lie at a distance of from 15 to 18 mm. ($\frac{3}{5}$ to $\frac{3}{4}$ in.) beneath the cortex. The facial nerve is the structure which it is especially important to avoid in all mastoid operations. There are two places in its course where it is most likely to be exposed to injury in operative procedures upon this bone. The first point is situated in the horizontal portion and elbow of the facial canal, where it passes under the aditus ad antrum. When the nerve is wounded here it is generally due to the careless use of the curette when employed for removing granulations from the epitympanic space. The second point where the nerve is liable to injury is near its exit from the stylo-mastoid foramen. It is apt to become involved at this point in those cases which are spoken of as instances of "Bezold's perforation"—cases in which perforation of the inner table or anterior surface of the mastoid process takes place. The nerve is also apt to receive damage at this point in infancy, because the undeveloped condition of the mastoid process leaves the stylo-mastoid foramen more exposed upon the lateral surface of the bone than is the case in adult life. The surgeon, in using his curette in those cases in which the cells lying above and behind the jugular bulb are involved, will have to exercise care so as to avoid wounding the facial nerve.

The only part of the internal ear which is apt to be encountered in operative work is the horizontal semicircular canal. This canal, which is surrounded by an eburnated sheet of bone and is situated just behind the inner wall of the aditus ad antrum, is rarely injured. In order to avoid injuring it, one needs only to be careful not to curette the inner walls of the antrum and of the aditus ad antrum.

The short process of the incus is another part which bears some relation to the aditus ad antrum. It rests upon the floor of this canal at its tympanic end.

The surgeon having recalled to memory the various landmarks and the relations between the structures which he expects to invade and those which he must avoid, is now ready to proceed with the operation.

As the first step, the large bone gouge is placed in contact with the bone at the upper border of the suprameatal fossa, and with it the surgeon proceeds to remove a long narrow sliver of bone extending from this point to the extreme tip of the mastoid process; that is, he uncovers that portion of the mastoid process where the external surface curves over to form the anterior surface. In taking this step he will gain some idea of the character of the mastoid process—whether it is made up of pneumatic or of diploëtic cellular structure, or whether it be sclerosed. He need have no fear of wounding the sinus, as it is almost impossible to do this unless it happen to lie immediately beneath the cortex of the mastoid process at the point where it curves in to form the external auditory canal—a position which it rarely occupies. However, if he is careful to hold the gouge firmly and at a very acute angle to the bone surface, he can scarcely injure the vessel even if it should occupy this very exceptional position, for the instrument would slip along its flexible surface and so in all likelihood would not wound it. From the vertical groove thus established he should proceed, with gouge or chisel and rongeur forceps (chiefly the latter), to remove the remaining cortex of the mastoid process. The chisel is used but little, except in sclerotic cases, after the cortex has been removed. The curette and the forceps are used to remove each of the cell partitions throughout the whole mastoid structure until the cells are entirely obliterated and the inner plate of the mastoid process is reached. This thin plate of bone, as will be remembered, is the only structure which separates the sinus and the dura of the posterior and middle cerebral fossæ from the pit made by the removal of the mastoid cells. If, upon careful examination, it shows evidences of being diseased, or if, though it should appear to be healthy, the history of the case is such as to warrant the suspicion that pathological conditions exist in either of these fossæ, or that the lateral sinus is involved, this plate of bone must be removed to permit of a thorough examination of the parts lying beyond.

If it should appear to some that the plan here advocated, of removing all the mastoid cells, is unnecessarily thorough, I will call their attention to the fact that, unless these structures are completely eradicated, some remote cell with its nidus of infection may be left behind, and then, weeks later, when the wound is still open, although apparently well on its way toward healing, we shall be forced to conclude, from the unsatisfactory manner in which the case is progressing, that we did not do our work thoroughly, and that the operation, with all its attendant dangers and worries, must be performed a second time. It is surprising to note how often, in the course of a mastoid operation, one encounters—at some point quite remote from the antrum and separated from it by other cells which to the unaided eye appear to be fairly normal or at all events free from the presence of anything like purulent material—a single cell filled with pus. Such a discovery is apt to be made among the cells situated in the posterior portion of the tip of the mastoid process, and occasionally also among those located in its upper and posterior portion.

As even the complete destruction of the distinctive mastoid cells cannot be trusted to eradicate all the sources of infection, it is advisable, in addition, to obliterate all the cellular structure located anteriorly to the antrum, above the external auditory canal, and at the root of the zygomatic process, as well as those cells in the petrous portion which lie between the posterior boundary of the antrum and the anterior and upper border of the sigmoid sinus, together with those other deeply situated cells which lie above and behind the jugular bulb.

It will generally be found best to remove the entire tip of the mastoid process, instead of leaving, as is often done, its inner surface, which serves no useful purpose. No anxiety need be felt about depriving the sterno-cleido-mastoid muscle of its bony support, for in course of time it forms new attachments. As a matter of fact, I have never seen a case in which the muscular movements of the head were at all interfered with as the result of the removal of this plate of bone.

The aditus ad antrum ought to be gently curetted and freed of all granulations and carious bone, otherwise the products of inflammation in the tympanic cavity will be prevented from properly draining through the posterior wound.

If for any reason—as, for example, when a sinus is situated very far forward—the antrum cannot be reached in the usual way, it may be necessary to enter by way of the bony external auditory canal. By separating the soft tissues from their bony support the upper and posterior bony wall of the external auditory canal may be removed with the chisel and the antrum opened, care being taken to avoid breaking the tympanic ring and entering the tympanic cavity.

In carrying out the operation in the manner here described the surgeon will always have before him a broad and open field in which there are no obscure pockets. If he chance to wound the sinus—an accident which is generally the result of undue haste—he will experience no difficulty in controlling the hemorrhage by the simple application of an iodoform-gauze tampon; and afterward he may proceed with the operation by working around this tampon,—a procedure which could not so readily be carried out if the sinus had been wounded while he was working at the bottom of a deep cavity.

It is important to use the probe freely, as the operation proceeds, so as to ascertain whether or not the granulations are lining a bony cavity or are springing from the dura mater or sinus and protruding into the mastoid cells through an opening in the inner table. Unless this precaution is taken, it is easy, while using the curette, to wound the exposed dura mater or to plunge into the sinus. The probe should also be used for the purpose of searching most carefully for the existence of any possible fistulous channel, which may lead through the inner table into either the middle or the posterior fossa. If such a sinus is found to exist, it should be enlarged sufficiently to permit of the easy examination of the underlying tissues. This careful investigation is absolutely necessary, for it is by means of such a thorough probing that many a case of unsuspected perisinous abscess, or of extradural abscess, has been discovered.

In cases of perforation through the posterior wall of the external auditory canal this bony partition will have to be removed to a limited extent and the adjacent soft tissues carefully curetted. It is rarely necessary, in acute cases, to remove that portion of the posterior wall which includes the tympanic ring.

If the mastoid process is one that contains few pneumatic cells, the surgeon, in performing the operation, must adopt a course somewhat different from that which I have advocated above; he must first search for and find the antrum, and then from this point he should work toward the tip and posterior portion of the mastoid process until this process has been fully excavated. Such thorough excavation is as necessary in these cases of sclerosis as it is in those first described, for in this type of mastoid a large cell is often found remotely situated from the antrum, and yet filled with pus. In fact, I have operated upon cases in which, while the antrum and adjacent cells were apparently free from purulent matter, a cell located posteriorly and near the tip has been found to be full of pus.

In cases in which a perforation has already taken place spontaneously in the cortex of the mastoid, the use of the chisel is unnecessary; the surgeon may begin at once with the curette and follow the fistulous track which exists and which always leads into the antrum. After he has reached this cavity he may proceed with curettes and forceps as in the first type of cases. In following such a fistulous track, however, considerable caution is needed if one wishes to avoid plunging into an uncovered lateral sinus.

When the surgeon is positive that every pneumatic cell of the mastoid process has been excavated,—in other words, after he has performed thoroughly the work which he set before himself at the beginning, viz., that of removing from the mastoid region every vestige of infective material,—and after he has carefully smoothed down all the rough places both on the inner table of the mastoid process and along the edges of the excavation in the bone, he may either cleanse the cavity with a normal salt solution or simply mop the surface with dry sterile gauze. If the posterior or the middle cerebral fossa has been opened, he should first fill the cavity with alcohol and then wash it out with the normal salt solution. (In children particular care should be taken not to use such solutions as one of bichloride of mercury, on account of the ease with which solutions pass through the Eustachian tube into the throat.)

In syringing the wound no forcible effort ought ever to be made in an endeavor to have the solution pass through from the opened antrum into the tympanic cavity, and thence through the external auditory canal. If the operator can readily pass his probe into the tympanic cavity he has accomplished one of the important objects of the operation, viz., to establish tympanic drainage posteriorly, and it is not necessary to force fluids through the membrana tympani and external auditory canal. After the excavation has been cleansed, the next step is to place ligatures upon any vessels which can not be controlled by pressure, then to close with silkworm-gut sutures the posterior cutaneous incision, if one has been made, and, finally, to close in the same manner the upper angle of the auricular incision as far as the level of the bony margin of the wound. The remainder of the incision is left open. The cavity of the wound is packed with iodoform gauze, which should be carried well down to the bottom of the wound for the first dressing; and a small wick of sterile gauze is also inserted into the external auditory canal as far as the membrana tympani. This last measure provides for proper drainage and prevents the retention of any secretions in the tympanic cavity. The wound and the auricle are then covered with sterile gauze and a bandage is applied over all. This external dressing is left in place until the sixth or seventh day (unless pain or a rise of temperature indicates the necessity for its earlier removal).

In many cases a post-operation fever will occur on the day after the operation, and in infants and young children the temperature is very likely to rise as high as 102° F. If the fever continues on the second and third days it may be due to wound infection or to some complication; and under these circumstances the dressings should be removed and the parts examined. The cavity at each dressing is dry-cleansed, a sterile gauze dressing is very loosely placed in it, and the external dressings are applied as before. The sutures are removed on the seventh or eighth day. If the case has been one of simple mastoiditis, it is seldom requisite to keep the patient in bed for more than from seven to ten days. In all the later dressings a special effort should be made to secure an even growth of the granulations around the bottom of the wound, and to prevent healing of the outside of the wound before the cavity is filled with healthy granulation tissue.

In patients who give a history of good general health healing may be expected to take place in from four to six weeks; while in those who have previously had ill-health the healing may be delayed for as many months. The after-care of the case is one that requires much judgment. Irrigation, especially with a solution of bichloride of mercury, is injurious to the delicate granulations which are endeavoring to fill the cavity. For cleansing the latter, careful use should be made of pledgets of dry gauze or of pledgets of absorbent cotton moistened in sterile water. After the first few dressings the wound should be packed with simple sterile rather than with iodoform gauze, as the latter tends to promote exuberant granulations. The packing should be introduced somewhat loosely, the quantity of gauze used being simply sufficient to absorb the discharge and to prevent the superficial union of the tissues. The scissors or the curette may be used for the removal of exuberant granulations, which at times form along the edges of the wound. To stimulate the formation of granulations on the bone, in cases which are slow to heal, an application of pure carbolic acid, followed immediately by one of absolute alcohol, will be found advantageous. Balsam of Peru or a solution of silver nitrate, of a strength of from forty to sixty grains to the ounce of distilled water, may also be used. Insufflations of boric acid, of subgallate of bismuth, or of xeroform, are of assistance in cases in which there is much discharge, as also in those in which the healing process is nearly completed. If the operation has been thoroughly performed it will seldom be necessary to call to our aid any of these chemical agents which promote healing.

After the first few dressings the gauze bandage (Johnson and Johnson manufacture a black gauze bandage, which is less conspicuous than the white one) may give way to a black silk pad which is tied over the wound by means of tapes passed around the head. When the wound becomes small enough, the dressing may be fastened to the skin by means of flexible collodion.

In a few cases the otorrhœa may persist. This is more likely to happen in neglected cases, where the operation has not been performed early enough, or in cases of a very virulent type. Under such circumstances one may expect to find the mucous membrane of the tympanic cavity covered with granulations, or some portion of its bony wall in a necrosed state, or one or more of the ossicles similarly affected. Systematic cleansing of the canal with sterile salt solution or a boric-acid solution may suffice in some of these cases to arrest the otorrhœa; but if granulations have formed or if there be a limited necrosis of bone structure, it will be necessary to employ a Buck's sharp-edged curette or a Hartmann's cutting forceps. A bead of silver nitrate fused on the end of a slender probe may be used for destroying the granulations, and the instillation of a few drops of a saturated solution of iodoform or of boric acid in seventy-five per cent alcohol may be found useful in effecting a cure. In some of the cases, however, no medication or simple surgical procedure will suffice to effect a cure, and an ossiculectomy or even a radical mastoid operation may be necessary.

The Blood-Clot Method of Inducing Healing of the Mastoid Wound.—This method may be adopted in those cases in which the tissues, during the operation, have been subjected to very little bruising, and in which all granulations and all shreds of tissue have been carefully removed from the antrum and aditus. After the cavity has been irrigated with a sterile saline solution and then wiped dry, it is allowed to fill with blood. No chemical solutions are to be used. When the cavity is filled with blood the overlying soft parts are brought together and sutured subcutaneously with silver wire or silkworm gut. In carrying out this method it is necessary to employ the strictest asepsis; and when it proves successful this procedure shortens very materially the time of healing. Very little if any depression remains behind the auricle after the wound has healed, and the scar in a very short time is scarcely discernible. If the blood-clot becomes infected the suture is removed and the case is dressed as an open wound, as described on a previous page.

VI. CHRONIC PURULENT INFLAMMATION OF THE MIDDLE EAR.

That this disease is one of great importance and associated with grave danger, is clearly shown by the fact that life-insurance companies will not accept as a risk a person so afflicted. The danger lies in an extension of the infection to the dura mater of the brain, to the cerebral or cerebellar structures, or to the lateral sinus.

The disease generally begins as an acute purulent inflammation of the middle ear, and, as a result of neglect or in consequence of unsuitable treatment, there gradually develop in the mucous membrane of that cavity a variety of pathological alterations—hypertrophy, the formation of adhesive bands between the various structures contained within the tympanic cavity, ulceration of the mucoperiosteum with its attendant bone necrosis, etc.—which tend to perpetuate indefinitely the purulent discharge by way of the external auditory canal.

Symptoms and Appearances Observed on Otoscopic Examination.—The symptoms vary very much. In some cases there is only a very slight discharge to which the patient gives little or no heed; in fact, he is often unaware of its presence, as it frequently dries on the wall of the canal. In other cases the discharge is very profuse and no other symptoms are present. All nasal or naso-pharyngeal lesions aggravate the disease most markedly. The discharge may be thick, muco-purulent, and non-odorous, from which facts one may infer that the bone is not affected; or the discharge may be distinctly purulent and have an offensive odor, as occurs when the bone is diseased. When granulations or polypi exist, the discharge is generally sanguineous.

On otoscopic examination, if no polypi or exuberant granulations are present, it will be seen that the drum membrane is thickened and is perforated in one or more places. The perforation may be of small or of large size, or the destruction of the drum membrane may have been so complete that only a narrow rim remains at the periphery. The location of the perforation in the drum membrane has much significance. A perforation near the margin generally means that some bone necrosis exists in the vicinity. A central perforation generally denotes an absence of bone necrosis. A perforation over the mouth of the Eustachian tube generally means a stenosis of this tube complicating a nasal or naso-pharyngeal lesion. A perforation located in Shrapnell's membrane points, as a rule, to the existence of bone necrosis in the epitympanic space; a perforation in Prussak's space generally means a necrosis of the head of the malleus; a perforation in front of the incus is usually associated with a necrosis of this bone or of the walls of the mastoid antrum.

According to Randall, perforations occur most frequently in the posterior inferior segment (372 in 1,000 cases); next, in the anterior inferior (257 in 1,000 cases), then in the posterior superior segment (164 in 1,000 cases). Central perforations (often too large for the region of origin to be longer determinable) are observed in 70 out of 1,000 cases. Randall remarks, however, that if a larger number of observations were available it might perhaps be found that perforations occurred more frequently in the upper posterior segment than is indicated by the figures given above.

Prognosis.—The individual cases differ so greatly, as regards the pathological conditions which are present, that it is not possible to make any general statement with reference to the prognosis. Each case will have to be studied by itself, and even then it will not be possible to give more than a very guarded prognosis, especially in reference to the recovery of any material part of the lost hearing. The arrest of the discharge and the removal of all danger to life from the presence of bone disease in close proximity to a vital part may be safely predicted in the majority of cases provided the patient will submit to the operative treatment required. But if the disease is allowed to run on, the prognosis is generally bad.

Treatment.—The local employment of drugs is often unsatisfactory. The discharge may be stopped for a time, but in most cases it soon returns. Search should be made for lesions in the nares or post-nasal cavities, and, if any exist, they should be thoroughly treated; otherwise local treatment of the middle-ear tract will be useless. As in all surgical diseases, perfect drainage is absolutely necessary. To accomplish this, it is necessary to remove all exuberant granulations or polypi, to enlarge the opening in the drum membrane if it be too small, or to extend it downward to the lower margin of the tympanic ring; or even to make an entirely new perforation, if, by doing so, better drainage may be secured. The discharge may be removed either by means of dry cleansing or by intra-tympanic injections of a normal saline solution or a mild aseptic solution, to be followed by wiping the parts dry with small pledgets of sterile cotton. Injections through the Eustachian tube will greatly assist in the cleansing of the tympanic cavity. These injections may be readily made by means of a Weber-Liel catheter, which consists of a slender but long flexible rubber catheter placed inside the ordinary Eustachian catheter. These catheters, one within the other, are introduced in the usual manner through the nose and inserted into the mouth of the Eustachian tube. The smaller one is next pushed into the tube as far as the isthmus. Then by means of a syringe containing a saline solution, and attached to the inner catheter, the tympanic cavity may be thoroughly cleansed. Alcoholic solutions, either alone or combined with boric acid or iodoform, or a weak solution of silver nitrate or of an albuminate of silver (argyrol) may be employed beneficially in many of these cases. These solutions may either be injected into the tympanic cavity through the perforation in the drum membrane or be introduced by means of the Eustachian catheter.

If there is caries of the ossicles or of the epitympanic space, it may be found necessary to perform an ossiculectomy in order to gain the room needed for proper drainage and for treating the diseased area. If any one or all of these methods, briefly outlined here, fail, the case then demands that some one of the methods described further on under the heading of Radical Mastoid Operations will have to be employed.

Aural Polypi.

The aural polypus is always a product of otogenic suppuration. Polypi may be either fibrous or myxomatous in character. By preventing the proper drainage of a suppurating ear they may indirectly cause an extensive caries of the cavities of the middle ear with its attendant complications. After the surgeon has ascertained that a polypus exists in the ear, and before he proceeds to determine the starting-point and the character of its pedicle, he should instill into the canal, first, a four-per-cent solution of cocaine, and then a 1-to-1,000 solution of adrenalin. After about fifteen minutes he may then with a probe endeavor to ascertain the facts he seeks. Most polypi develop on the wall of

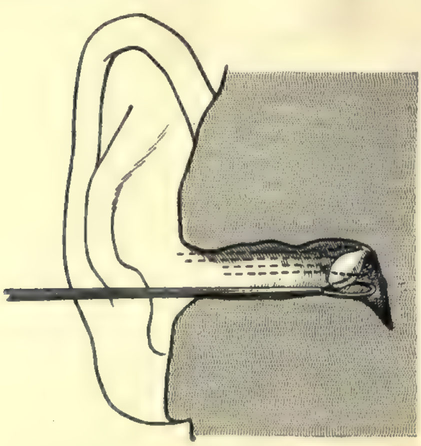

Fig. 347.

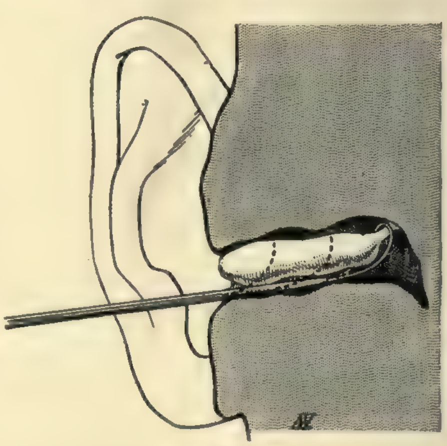

Fig. 348.

Figs. 347 and 348.—Diagrams Showing the Methods that May Be Employed in Removing a Polypus by Means of a Wire Snare. (Laurens.)

the tympanic cavity, while only a few spring from some portion of the external auditory canal near the drum membrane.

If the polypus is small the site and size of its pedicle are easily determined, but when the growth is large and occupies the whole lumen of the canal it is often a difficult matter to discover the situation and starting-point of the pedicle. Armed with a probe the surgeon gently explores the surface of the polypus at different depths until he meets with an obstruction, which he may assume to be a portion at least of the pedicle. In this manner he may map out with sufficient accuracy the position and starting-point of the growth.

Polypi may be removed by means of the wire snare, the curette or the forceps, or by chemical or galvanic cauterization.

The snare is the instrument that best suits the majority of cases. General anæsthesia is preferable to local anæsthesia.

Having ascertained the situation of the pedicle the surgeon makes the loop of the wire snare large enough to encircle the polypus and at the same time sufficiently small to pass through the aural speculum. The ease with which the loop may be passed down over the polypus as far as its root depends upon the size, shape, and situation of the growth and its pedicle. In some cases it will be very easy to accomplish this (see Fig. 347), while in others it will be more difficult (see Fig. 348). In a few cases the ingenuity of the operator will be severely taxed. One must exercise, not only care, but considerable gentleness, as otherwise damage may be done. For example, one of the ossicles may be removed or the facial nerve damaged. Ordinarily, such accidents only occur with gross carelessness, but sometimes the parts damaged are so surrounded with newly formed tissue as to be easily endangered. Occasionally, when the polypus has a broad base, it may be necessary to remove it with the curette. The danger in removing an aural polypus lies in the possibility of lighting up a new source of infection which may extend to the cranial contents. Hence the necessity of observing perfect asepsis throughout the entire operation. Sterile-gauze drainage in the canal is all the dressing that is required.

Cholesteatoma.

Cholesteatoma is a tumor formed by the exfoliation of epithelial scales which become agglutinated in concentric layers, and between which are found cholesterin crystals. These tumors, which vary in size from a small seed to a large hickory nut, are of a gray color and present a glistening appearance. They give off an offensive odor and, partly by pressure and partly through a process of necrosis, they cause the destruction or disappearance of adjacent bone tissue. Ultimately they may give rise to an infective labyrinthitis or a basilar meningitis.

These tumors may lie dormant for years without giving rise to any symptoms. Then, from some such cause as sea-bathing, syringing of the ear, etc., they may swell and give rise to pressure symptoms, viz., headache, nausea, vertigo, dizziness, uncertain gait and general malaise, attended with fever.

A diagnosis may be made by examining under the microscope particles of the mass that may be removed by means of a curette or that may come away in the intratympanic syringing. If crystals of cholesterin be found, the diagnosis is certain.

The radical mastoid operation may bring about a cure; but, on the other hand, the disease may persist because of the remaining focal centres left in the Haversian canals of what appears to be healthy bone.

The only possible means of curing this form of disease is to remove in a thorough manner all the bone involved.

Ossiculectomy.

There are two different conditions under which the operation of ossiculectomy has hitherto been performed. In one of them the middle ear is the seat of a chronic catarrhal otitis media, characterized by ankylosis of the malleus and incus, but not—so far as can be ascertained—by an ankylosed condition of

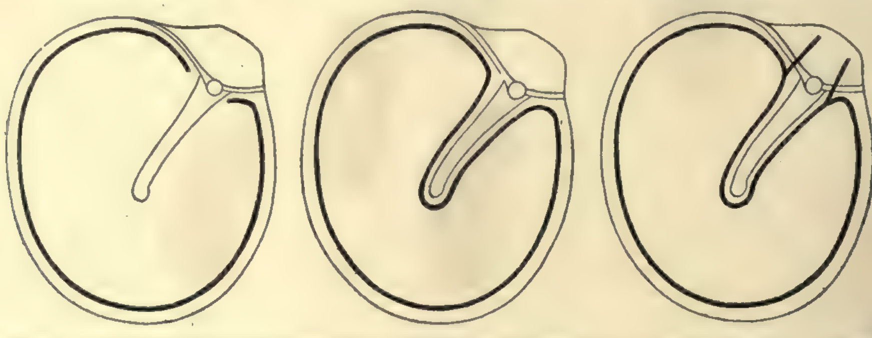

Fig. 349.—Lines of Incision for Removing the Tympanic Membrane in the Operation of Ossiculectomy. (Laurens.)

the foot-plate of the stapes in the oval window. In these cases it was assumed that the removal of the two immovable ossicles (malleus and incus) would enable the waves of sound to impinge with greater force upon the foot-plate of the stapes, or—in other words—would improve the hearing in this ear. However, the results obtained from the operation in this class of cases were in so many instances unsatisfactory that there are to-day very few aural surgeons who advise and perform it. In chronic purulent inflammation of the middle ear, on the other hand, ossiculectomy is performed for an entirely different purpose, viz., for that of increasing the breadth of the outlet from the epitympanic space and antrum into the cavity below. For a number of years the operation was discontinued in favor of the more certain radical mastoid operation, but at the present time it is again coming into favor in the treatment of certain cases, viz., those in which the disease is limited to the tympanic cavity and does not involve the mastoid antrum.

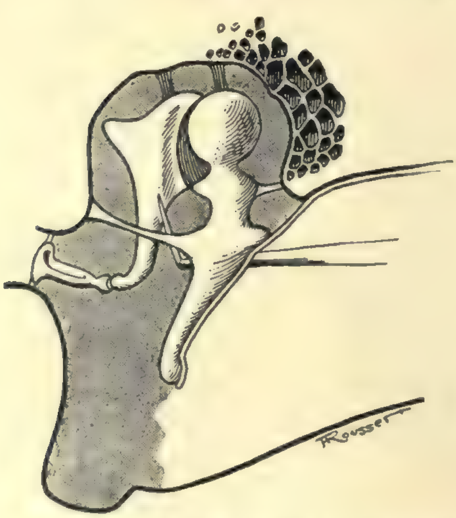

Fig. 350.—The knife is placed in front of the incus, ready to sever the tendon of the tensor tympani muscle. (Laurens.)

The Operation as Performed in Cases Where There Is No Destruction of the

Membrana Tympani.—The operation may be performed under cocaine anæsthesia; but it is preferable, in the majority of cases, to employ a general anæsthetic. Some aurists use, for securing local anæsthesia, equal parts of cocaine, carbolic acid, and menthol. A few drops of this mixture are instilled into the canal of the ear, and, after twenty minutes, complete anæsthesia will generally be found to be present.

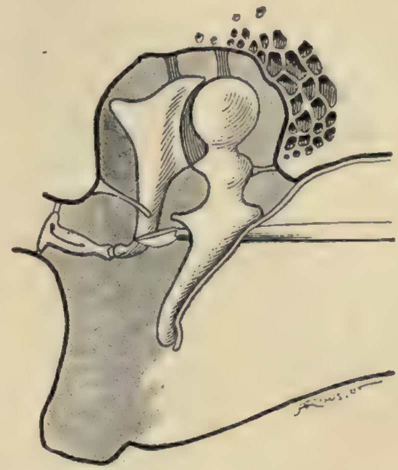

Fig. 351.—The tendon of the tensor tympani muscle has been divided; the knife has not yet been removed from the cavity. (Laurens.)

The external auditory canal should be rendered as aseptic as possible. This may be accomplished by gently scrubbing the canal with pledgets of cotton dipped in tincture of green soap and then flushing it with alcohol of ninety-five-per-cent strength. The incision is begun underneath the anterior ligament near its junction with the malleus handle; it is carried forward beneath the ligament to the tympanic ring, and then, from this point, it follows the margin of the drum membrane as far as the posterior ligament. It is carried from this point below the posterior ligament to the malleus handle. The knife then hugs the side of the handle of the malleus down to its tip and finally upward to the point of the beginning of the incision. (Fig. 349.) It is best at this point to instil into the tympanic cavity ten or twelve drops of an adrenalin solution, and then, after it has remained there for ten or fifteen minutes, to proceed with the operation. Shrapnell's membrane is divided both in front and behind the neck of the malleus; then, with an angular knife inserted in between the long process of the incus and the handle of the malleus, with the point of the blade pointing anteriorly, the ligament of the tensor tympani muscle is divided. (Figs. 350 and 351.) With a straight knife the superior ligaments of both the malleus and the incus are divided. (Fig. 352.) The ligaments attaching the head of the malleus to the external wall of the epitympanic space are divided. The malleus is then seized with a forceps high up near its head, and by

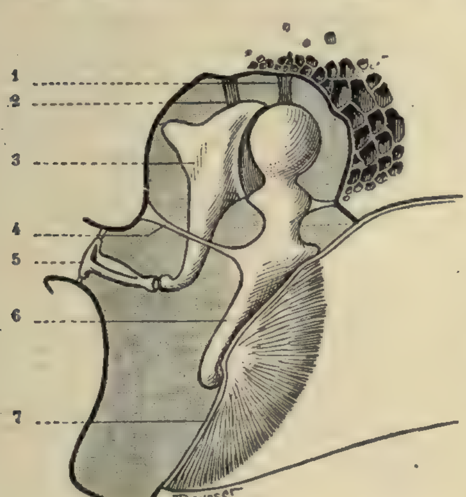

Fig. 352.—Diagram Showing the Relations of the Different Structures in the Tympanic Cavity to Each Other and to the External Auditory Canal. (Laurens.) 1, Suspensory ligament of the malleus; 2, suspensory ligament of the incus; 3, incus; 4, tendon of the tensor tympani muscle; 5, foot plate of the stapes; 6, handle of the malleus; 7, drum membrane.

means of a rocking motion, combined with a downward pull, it is removed. With an angular knife the incudo-stapedial joint is severed, and then, with the incus hook inserted behind the body of the incus, this latter bone is removed by rotating it forward and downward. The stapes is not disturbed. Immediately after the operation the cavity is flushed with alcohol and wiped dry, and a piece of sterile gauze is inserted. The after-treatment consists in keeping the parts clean, preventing the growth of any granulations, and keeping the canal packed with sterile gauze.

The operative technique as described above will have to be modified in cases of chronic purulent otitis media in which there has been more or less destruction of the membrana tympani together with other pathological adhesions in the tympanic cavity.

Synechtomy.

Synechiæ may exist between the handle of the malleus and the promontory of the middle ear, either in the shape of cord-like bands that stretch from one part to the other, or in that of short fibres which establish a direct union between it and the promontory. (Fig. 353.) There may also be a union between the drum membrane itself and the promontory. (Fig. 354.) Still other varieties of

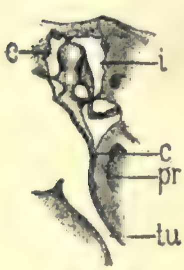

Fig. 353.

Fig. 354.

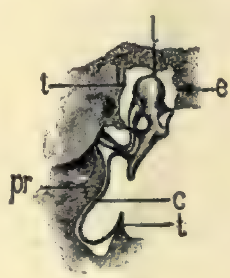

Fig. 355.

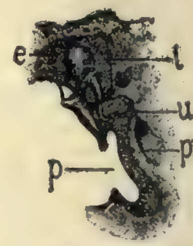

Fig. 356.

Fig. 353.—Diagram Showing the End of the Handle of the Malleus Bound Down tightly to the Promontory. The Eustachian tube opens almost directly into the external auditory canal. (Politzer.) *pr*, Promontory; *c*, end of the handle of the malleus; *e*, external, *i*, internal wall of the epitympanic space; *tu*, Eustachian tube.

Fig. 354.—Depressed Cicatrix of the Membrana Tympani Adherent to the Promontory. (Politzer.) *c*, Point where the cicatrix is adherent to the minor wall of the tympanic cavity; *i*, inner, *e*, outer wall of the epitympanic space.

Fig. 355.—Depressed Cicatrix of the Membrana Tympani Adherent to the Promontory of the Middle Ear and to the Incudo-stapedial Articulation. (Politzer.) *c*, Cicatrix adherent to the promontory (*pr*); *t*, the unyielding peripheral (cartilaginous) portion of the drum membrane; *l*, the suspensory ligament of the malleus; *i*, inner, *e*, outer wall of the epitympanic space.

Fig. 356.—Tympanic Cavity Obliterated and Its Contents (membrana tympani, ossicles, etc.) Embedded in a Mass of Newly Formed Tissue. (Politzer.) *p*, Pocket formed by the depressed and adherent drum membrane; *pr*, promontory; *u*, niche for the oval window obliterated by newly formed tissue; *i*, inner, *e*, outer wall of the epitympanic space.

adhesions are shown in Figs. 355 and 356). These adhesions occur in both the purulent and the non-purulent forms of middle-ear disease and are productive of deafness and tinnitus.

If a perforation is present, the diagnosis may be readily made by means of otoscopy alone or in connection with the use of an exploring probe. In chronic catarrhal disease of the middle ear the diagnosis is not so easily made.

The Operation.—Before operating, the surgeon should make sure that the deafness or the tinnitus is not due to labyrinthine disease or to ankylosis of the foot-plate of the stapes in the oval window, for if either of these conditions exists the operation of synechtomy is useless. The operation may be done under general anæsthesia, or, if a perforation exists in the drum membrane, it may be done under cocaine anæsthesia. In cases of perforation, adrenalin solution should be instilled into the tympanic cavity and left there for fifteen or twenty minutes. The adhesions are divided by means of left-angular or right-angular knives. In cases where no perforation exists, a myringotomy will have to be done. The adrenalin solution should then be instilled through the incision, and after twenty minutes the knife may be introduced and the adhesions cut through. Following the operation, inflations by means of the Eustachian catheter should be practised daily, for a week or ten days. A little sterile gauze placed at the inner end of the canal is all that is necessary.

VII. MASTOID OPERATIONS APPLICABLE TO CASES OF CHRONIC PURULENT INFLAMMATION OF THE MIDDLE EAR.

1. **The Radical Mastoid Operation, or the Schwartze-Stacke Operation.**—Introductory Remarks.—This operation is undertaken for the purpose of curing cases of chronic purulent inflammation of the middle ear in which the actual disease is not confined to the lower portion of the tympanic cavity and the cells around the tympanic end of the Eustachian tube, but consists of a caries of one or more of the ossicles, of some portion of the walls of the epitympanic space, of the mastoid antrum, and of the adjacent cells. The disease may or may not be accompanied by a cholesteatomatous condition of these cavities.

By means of the operation the surgeon seeks to establish a single large cavity which shall consist of the excavated mastoid cells, the tympanic cavity, and the external auditory canal; this cavity eventually to be lined with a non-secreting epidermal membrane.

The question of operative or non-operative interference in cases of chronic purulent discharge from the middle ear is as yet a mooted question with otologists; that is, some surgeons naturally radical will operate where others more conservative will try the effects of locally applied remedies. Professor Macewen's rule is: "When a pyogenic lesion exists in the middle ear or its adnexa, which is either not accessible or which cannot be effectually eradicated through the external ear, the mastoid antrum and cells ought to be opened." This is, in a sense, a good broad view, but it may be interpreted in different ways by different operators. For example, they are not likely to agree as to the accessibility of the diseased area; one class of men believing that an ossiculectomy, with removal of the diseased tissues of the tympanic cavity, will render accessible the necrotic area and will bring about the desired cure, while another class of men maintain with equal positiveness that the results of an ossiculectomy are unsatisfactory. Again, as to the possibility of effectually eradicating the disease by working through the external ear, some men, who have given the method a careful trial for a period of several months, claim that it is impossible, in a given case, to accomplish a cure in any other way than by a radical operation. Then, again, there are others who, in a similar case, persevere in this local method of treatment for a year or more and finally obtain a cure. Some believe that in those cases in which the discharge is intermittent the operative plan should be adopted, while others maintain that in these cases one may, without risk of jeopardizing the patient's health or life, advise against an operation provided he will be careful to have his ear examined at short intervals. Case upon case may be cited to support each one of these different views, and, as a still further enhancement of the difficulties of the question, all operators admit having opened mastoids in which the gross pathological lesions were insignificant and wholly out of harmony with the grave character of the symptoms which led to the performance of the operation. The reverse has also been the experience of these same men; they have found great destruction of tissue in cases in which there were but few and not very serious symptoms. Finally, cases are observed in which, within a few hours, the previously insignificant symptoms give place to others of the gravest import.

Chronic purulent inflammation of the middle ear is the direct cause of from thirty (Pitt) to fifty (Barr) per cent of the brain abscesses that occur. It is estimated that in this country about four thousand cases of brain abscess of otitic origin end in death annually. According to Koerner the Prussian statistics for 1885 give a death-rate of otitic brain abscess three times as great as this for each ten thousand of population, or 1.5 deaths from this cause for each ten thousand of population. A fairly large percentage* of the cases of leptomeningitis, of pachymeningitis, of pyæmic sinus-thrombosis, and, to a less degree, of septic pneumonia, pleurisy, etc., are of otitic origin. To prevent the development of these most serious complications the aural surgeon should urge the necessity of dealing with every case of chronic purulent discharge from the middle ear as something not to be lightly regarded, but as a disease which must be eradicated, no matter how innocent a case it apparently may be. The disease is capable of advancing most insidiously, and frequently without any symptoms, until a very extensive destruction, not alone of the tympanic cavity and its adnexa, but of the brain tissues as well, has taken place. Brain abscesses have often been found at the autopsy to have been the cause of death when no such lesion was suspected in life. Macewen says "that one who has a chronic purulent otitis media is liable to have, with very little warning, a most serious or even a fatal illness. Acute

* About five per cent of all cases of meningitis and two-thirds of all cases of sinus-phlebitis are of otitic origin. (Pitt.) In 17,028 autopsies in London death was due in 102 (or 1 in 167) to an otitic lesion. In 10,707 cases with tympanic suppuration 69 deaths occurred as the result of the aural lesion, or 1 in 155. (Koerner.) In 38,017 aural patients death occurred, as the result of the disease, in 119, or 1 in 319. (Buerkner's and Randall's individual statistics combined.)

or chronic disease of the middle ear is a disease that is fraught with much danger to life and should always be regarded most seriously."

Indications for the Performance of the Radical Mastoid Operation.—The question of operative or non-operative interference in prolonged suppuration from the middle ear is not a difficult one to decide if all the symptoms of an acute exacerbation of the inflammation in the mastoid antrum and vicinity are present. For example, if a fistula exists in the mastoid process; if it can be demonstrated that a cholesteatomatous mass occupies the region of the antrum or adjacent cells; if, after repeated removals, granulation tissue is still reproduced in the tympanic cavity; if facial paralysis is present; if, in consequence of a narrowing of the external auditory canal, the discharge from the deeper parts cannot escape freely; if vertigo is present or if there are recurring attacks of mastoid tenderness, there can be no question as to the need of operation, and this need becomes imperative if in addition there are headache, malaise, and elevated temperature. It is only in cases where, aside from an incurable discharge, there are no objective symptoms, that the surgeon hesitates; and even in these cases the consensus of opinion is in favor of operative interference, as the operation, although not devoid of danger, is less dangerous than the existing disease—or, as Grant states, "the responsibility is greater in deciding against than in deciding in favor of an operation."

Fig. 357.—The dotted line shows the line of incision required when the large anterior mastoid flap is to be used.

The Steps of the Operation.—The patient is prepared as is described above for the simple mastoid operation (p. 695).

The incision (Fig. 357) is carried from the antero-inferior border of the tip of the mastoid process in a curvilinear direction upward, backward, and then forward to a point above the insertion of the antero-superior angle of the auricle. The centre of this incision should be about one inch behind the centre of the posterior insertion of the auricle. This incision gives better results, especially from a cosmetic point of view, than does the incision made nearer the auricular insertion. In making the incision it is advisable to cut through all tissues down to the bone from the tip up to the temporal ridge, but from this point to the extreme end of the incision it is not necessary to cut any deeper than down to the aponeurosis which covers the temporal muscle. If a fistulous opening exists in the skin surface it is excised or the incision is made so as to include it. When the anterior flap is retracted it is pushed sufficiently far forward to expose the posterior bony wall of the external auditory canal. As the next step, the posterior wall of the membranous external auditory canal is separated from its bony support and made to lie flat on the anterior wall of the canal, thus exposing the entire upper and posterior wall of the bony canal as far as the tympanic ring. This should be done with great care, so as to avoid bruising the periosteum, which eventually forms the outer boundary of the cavity to be created. With this object in view, and at the same time to keep the flap out of the operator's way, a strip of sterile gauze should be passed into the external auditory canal and brought around so as to lie against the exposed posterior surface of the flap. The latter may then be drawn well forward by pulling upon the ends of the gauze strip. There is no need of disturbing the posterior flap. The spurting vessels should merely be clamped; those which simply ooze may be controlled by pressure. (Plate XXXVI, Fig. 2.)

The operation upon the bone is performed in the same manner as is the operation described for simple mastoiditis, up to the stage at which the latter is considered complete. In the course of his work, however, the operator will almost surely encounter conditions which are appreciably different from those observed in the ordinary operation. In the first place, he will find, as a rule, that the mastoid process is sclerosed and possesses few if any cells or pneumatic spaces, and consequently he will have to chisel his way through an ivory-like bone before he reaches the antrum. This cavity, when reached, may be found to contain cholesteatomatous material, thickened granulations, or inspissated pus. Then, again, it may be found that the tympanic roof has been eroded and that the exposed dura is covered with necrotic granulation tissue; or the inner plate of the mastoid process may have been destroyed, thus laying bare the wall of the sinus or the dura covering the cerebellum.

From this point onward in the operation, certain additional steps are required. The first of these consists in bending the tip of a pure-silver probe at nearly a right angle (the bent portion measuring about 6 or 7 mm. in length) and then passing it along the posterior wall of the external auditory canal into the tympanic cavity until its tip projects into the antrum. This probe serves as a guide to show how the facial nerve may be avoided while the upper and posterior canal wall is being removed. The bony channel containing this nerve lies underneath the probe under the floor of the aditus ad antrum. The mallet and chisel may be used in the removal of the major portion of the canal wall. When, however, the surgeon reaches the innermost part of this posterior wall he will have to remove a bridge of bone which has no support, and if, for the accomplishment of this, he employs the chisel, it may easily happen that he will remove a piece which is much larger than he intended to remove, and which may include the facial canal. On the other hand, with Jansen's forceps (Fig. 343, No. 3), especially curved for this purpose, he will experience no great difficulty in controlling the size of the fragment removed at each seizure. The piece of bone which will have to be removed at this point extends, like a partition, from the tympanic roof to the floor of the aditus ad antrum.

The course taken by the facial canal is from the petrous process of the temporal bone across the upper portion of the inner wall of the tympanic cavity and above the oval window. Then, dipping down beneath the floor of the aditus ad antrum, the canal passes downward, through the hard compact plate of bone which forms the base of the posterior wall of the external auditory canal, and terminates immediately behind the base of the styloid process. The nerve, when injured, is generally wounded above the oval window or on the floor of the aditus ad antrum; it is also sometimes injured near its exit from the skull.

The horizontal or external semicircular canal may also be wounded if care is not exercised. It is to be found in the compact mass of bone which forms the floor of the aditus ad antrum, a little above and behind the facial nerve, and if care is used in working on the floor of the antrum and of the aditus ad antrum no damage will result.

The posterior wall of the external auditory canal should next be removed, by shaving, until the bottom of the newly excavated part represents a plane extending from the floor of the aditus ad antrum to the floor of the bony portion of the external auditory canal. After it has been removed, the next step is to remove the ossicles or such portions of them as may remain. The removal of the two larger ossicles or of the necrotic stumps which may still remain *in situ*, is easily accomplished by seizing the incus with a pair of forceps, care being taken not to disturb the stapes, and then with an angular knife cutting through the incudo-stapedial joint. After this has been done, the removal of the incus, malleus, and remnants of drum membrane is easily accomplished. All granulation tissue in the tympanic cavity, especially in the vicinity of the pharyngeal end of the Eustachian tube and on the floor of the cavity, must be removed. The removal of the granulation tissue is best accomplished with the curette, which should be used with great caution, as it is with this instrument that damage to the facial nerve is most often done. It is therefore safer, before curetting, to use the probe, in order to determine whether or not the facial nerve is exposed. When it is exposed, the pressure of the probe will cause the muscles of the face to twitch. In curetting the cavity of the tympanum care must be exercised not to dislodge the stapes or to wound either the oval or the round window and thus possibly open up avenues of infection into the labyrinthine structures and thence very readily to the base of the brain. Displacement of the stapes results in a further loss of the already impaired hearing. If a loss of hearing does not occur immediately as the result of the operation, it is among the possibilities that a fixation of the stapes, with displacement, will occur as the result of the formation and subsequent contraction of newly formed tissues about its foot-plate. On the other hand, a permanent improvement of the hearing has sometimes followed the operation.

In order that the lower portion of the tympanic cavity may be properly drained it is generally necessary to remove a small portion of the lower canal and thus bring the external auditory canal on a level with the floor of the tympanic cavity. There, again, it is important to remember that the jugular bulb lies under the floor of the tympanic cavity, and that consequently one may easily wound it if care be not exercised. The tympanic end of the Eustachian tube should be thoroughly curetted so that it may be obliterated by the process of cicatrization and that thus the possibility of infection extending from the posterior nares to the tympanic cavity may be removed. The carotid artery lies in its canal below and behind the Eustachian tube. Hence the necessity of proceeding cautiously, when one curettes the posterior and inferior surfaces of the tube, lest injury be done to the artery. If any pathological condition is found to exist in the nares or naso-pharynx it should be attended to as soon as practicable, so that the middle ear may not be subjected to further infection or irritation from this source.

All portions of the tympanic cavity, as also of the mastoid cavity, should be smoothed down, and no projecting edges or points, which might impede the future epidermization of the cavities, should be allowed to remain.

Before proceeding to make the meatal flaps, the operator should carefully inspect the cavities for the possible existence of a sinus leading into the posterior or middle cranial fossa. If such a sinus is discovered, the bony structure through which it passes must all be removed and the underlying dura mater and sigmoid sinus inspected, so that, if any complicating lesion of the meninges, the sinus, or the brain itself exist, it shall not escape discovery.

In those cases of chronic suppuration which are associated with cholesteatoma the bone should be thoroughly searched for the presence of any fistulous track, and if one is found it should be thoroughly curetted. At no point should any but healthy bone, denuded of membrane, be left behind. Unless this is done a recurrence of the cholesteatoma is most likely to ensue.

When the surgeon has smoothed and rounded off all sharp edges of bone and is positive that he has removed all necrotic tissue, he may proceed to form, from the posterior portion of the membranous external auditory canal, the flaps which are to serve in large part as a lining membrane for the excavation in the bone. It is usual, at this point, to speak of dividing transversely the membranous external auditory canal near its inner extremity. I may state, however, that I have never seen a case in which the separation of the membranous lining of the canal from its bony support, which is done at an earlier stage of the operation, did not leave free its inner extremity and so render the making of this transverse incision unnecessary.

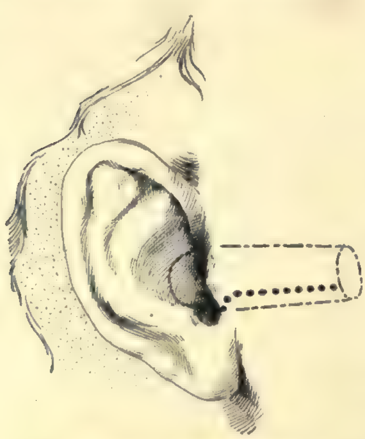

Fig. 358.—Diagram Showing the General Direction of the Shepherd's-Crook Incision as made in the Concha and thence extended into the External Auditory Canal. The broken lines indicate the location of the external auditory canal; the dotted line the direction of the incision.

The process of repair is much influenced by the manner in which the meatal flap is applied to the underlying surface of bone. This bone, it must be remembered, is frequently sclerosed and therefore scantily supplied with blood-vessels, and consequently it does not produce healthy granulations. The larger the flap and the more bone covered, the more rapid will be the reparative process; for the well-nourished flap rapidly unites with the bone and sends out granulations to cover the portion of bone left exposed. The meatal flap may be further aided by the employment of Thiersch's skin grafts to cover the exposed surfaces of bone.

Before any incisions are made to give the flap its proper shape all the muscular, fibrous, and areolar tissues underlying that portion of the external auditory canal and concha of the auricle which is to form this flap should be removed until nothing remains but the skin, with its subcutaneous connective tissue, and the cartilage which supports one end of the flap.

The First Method of Forming the Meatal Flap.—The flap that is probably employed in the majority of cases, and that is known as the "Ballance or shepherd's-crook flap," is made in the following manner:—First, the membranous external auditory canal is put on the stretch by introducing the blades of a slender artery clamp into the lumen of the canal and then separating the blades. Next, with straight, blunt-pointed scissors, the wall of the canal is slit, a little below the centre of its posterior surface, as far as the concha. Then, by means of a probe-pointed bistoury, the incision is extended into the concha in a curved direction, at first downward and backward, then upward and slightly backward, and finally slightly forward and upward until the root of the helix is reached. (Figs. 358 and 359.)

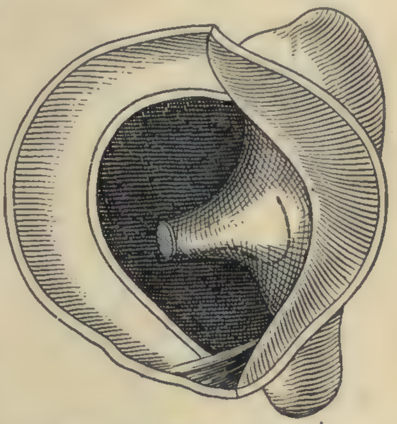

Fig. 359.—Diagram Showing the Large Semicircular Anterior Mastoid Flap Everted. The more darkly shaded area represents the exenterated mastoid cavity. To the right of this are the inner surface of the posterior wall of the external auditory canal and the inner surface of the concha. The dotted line indicates the shepherd's-crook incision, made for the purpose of forming the meatal flaps.

It might seem as if the large opening made in the region of the external auditory canal would produce an unsightly deformity, but this is not the case. In the course of six months, contraction takes place to such an extent that the meatus is but slightly larger than it was before the operation, and during the process of healing this large opening serves to render the dressing of the cavity much easier, more thorough, and less painful than if it were done through a smaller one.

By the method which we are now considering, two flaps are provided—a large superior one, which will cover the upper portion of the excavated mastoid cavity, and a smaller one which will completely cover the ridge in which lies the facial nerve. Any cartilage contained within the flaps should next be removed; then they should be anchored to the anterior flap of the mastoid wound by means of a catgut suture passing through the conchal end of each flap. The internal ends of the meatal flaps are placed in position against the bone and held there by means of gauze packing. The posterior mastoid wound is then entirely closed by subcutaneous silkworm-gut suture, the wound cavity is packed through the enlarged meatus with gauze, and the outer dressings are applied as in the simple mastoid operation.

If the method of operating here advocated is adopted, the raw surfaces of the meatal flaps will be brought in contact with the raw surfaces of the flaps of the mastoid incision and with the denuded bone of the excavation, and in due time firm union between them will take place. From the free edges of the deeper portions of these flaps a new growth of epithelium will take place, and gradually this new growth will extend over the granulating surface of the rest of the cavity. Thus, in the course of time, a non-secreting dermal lining will be supplied for the entire cavity which has been created by the breaking down of the partitions separating the mastoid cells, middle ear, and external auditory canal. After the healing is complete, a survey of the cavity will reveal the fact that a small ridge is located in its lower portion. This ridge, which is composed of the remainder of the posterior bony wall of the auditory canal, contains the facial nerve and divides the cavity into a posterior and an anterior half.

FIG. 360.—Lines of Incision as Made in the Concha in forming the Koerner Meatal Flap. (Laurens.)

In a few instances I have observed the development of facial paralysis at the end of a few hours, or even as late as a day or two, after the operation. I have attributed the phenomenon, which was only transient in character, to the pressure exerted upon an exposed facial nerve by the saturated dressings which filled the cavity, or to an inflammation extending from the severed and exposed chorda-tympani branch of the facial.

The Second Method of Forming the Meatal Flap.—In this method, which was devised by Koerner, the following steps are required:—A pair of artery or dressing forceps is introduced into the external auditory canal and held open so as to render tense its posterior cutaneous wall. Then, with straight blunt scissors, an incision is made in the membranous canal through the middle of its superior surface and extending from its freed extremity to the cavum conchæ. A similar and parallel incision is next made through the inferior surface of the canal. In this way there is formed, out of the posterior canal wall, a quadrilateral flap which is united to the auricle by a vertical line of union in the cavum conchæ. (Fig. 360.) This flap is then denuded of all muscular, fibrous areolar, and cartilaginous tissues. After it has thus been reduced in thickness and made pliable, it is turned backward into the mastoid wound (Fig. 361) and united, by means of two catgut ligatures passed through its free extremity, to the posterior flap of the mastoid incision. The next step is to unite the edges of the mastoid incision, as before described, throughout its entire length.

FIG. 361. — Diagram Showing the Second Step in Koerner's Method—viz., the turning of the meatal flap backward into the mastoid wound—completed. (Laurens.)

The excavated cavity in the mastoid is thoroughly dried and carefully packed with gauze through the meatal opening. Especial care should be taken to force the flap into close apposition with the periosteum of the mastoid flap and with as large a portion of the bony cavity as it can be made to cover.

The Third Method of Forming the Meatal Flap.—This method of providing a lining for the excavation in the bone was suggested by Panse. The first step in this procedure consists in carrying the incision through the middle of the posterior membranous wall of the external auditory canal as far outward as the cavum conchæ. From this point one incision is carried upward, at right angles to the first incision, as far as to the summit of the superior wall of the canal, while a second one is carried downward as far as the lowest point of the inferior wall, the two forming a T-shaped incision. As a result of these incisions there will be formed two flaps—an upper and a lower one. (Fig. 362.) Each of these two flaps is held in position against the underlying raw surfaces partly by a catgut ligature and partly by means of a gauze tampon. The superior flap is sutured to the periosteum at the upper anterior angle of the mastoid incision, and the inferior flap to the lower angle of the same incision. The extremities of the flap are held in apposition with the bone by gauze packing. These flaps are denuded of all underlying tissues, as was described in the making of the other flaps.

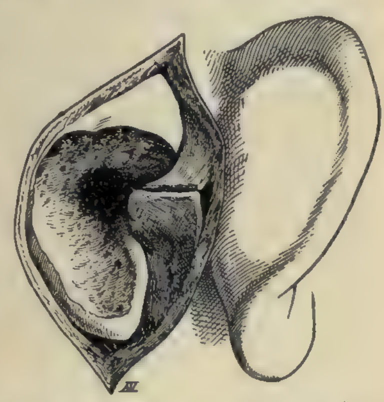

Fig. 362.—Shows line of incision made to form the Panse meatal flaps.

The Fourth Method of Forming the Meatal Flap.—This method was suggested by Stacke. According to his plan, the flap is made by carrying an incision through the middle of the superior wall of the external auditory canal as far outward as the concha, while from the termination of this first incision a second one is carried at right angles to the first downward as far as the lowest point of the inferior wall of the canal. The flap thus formed is pushed downward into the excavation in the bone and held in place by a gauze tampon and by a catgut ligature which unites its outer extremity with the mastoid flaps and the lower angle of the incision. This flap is of especial service in cases where the sinus or jugular bulb has been accidentally or intentionally exposed.

The Fifth Method of Forming the Meatal Flap.—In this method the flap is constructed by making the incision through the inferior cutaneous wall, instead of the superior cutaneous wall, and, in addition, a second incision is carried at right angles to the first upward to the superior wall of the canal. By means of gauze packing, the flap is held in apposition with the upper and posterior wall of the mastoid cavity rather than with the lower and posterior wall, as in the preceding method. This method of forming and managing a meatal flap should be used in cases where the dura in the middle fossa has been exposed.

After-treatment.—In the class of cases which we are here considering, the after-treatment requires much judgment. Irrigation should not be resorted to; as a substitute, very gentle dry cleansing with moist sterile-cotton pledgets is to be preferred. The first dressing need not be disturbed for six or seven days unless the temperature denotes a septic disturbance. Afterward, however, the wound will have to be dressed every day or every other day. The subcutaneous suture is generally removed at the time of the first dressing, when union will be found to have taken place between the external cutaneous flaps. As a protection a small dressing of sterile cotton is applied over the mastoid wound and fastened in place by means of flexible collodion. At the second or the third dressing this may be dispensed with. At each dressing, if much secretion is present, the cavity should be dusted with finely powdered boracic acid or with subgallate of bismuth, and a loose packing of sterile gauze should be inserted. The cavity must not be allowed to become obliterated by excessive granulations, and the strictest asepsis should be employed so as to prevent the possibility of a perichondritis—an accident which is liable to occur on account of the cartilage of the auricle having been opened in the making of the flap. If perichondritis arises, marked deformity is sure to follow. It is well to apply carbolic acid to the edges of the cartilage, with the view of preventing such an unpleasant accident.

FIG. 363.—Copied from a photograph taken on the tenth day following a radical mastoid operation. The incision, in this case, was made close to the auricle, and interrupted sutures were used. (Author's case.)

If the case that has been operated upon is one in which an acute exacerbation had previously taken place, with the formation of a subperiosteal abscess and perforation through the skin, it may be impossible to obtain, from the immediate vicinity, enough healthy skin to cover the exposed portion of the mastoid. When this is found to be the case, the difficulty may be overcome by resorting, at some later date, to a plastic operation, or by transplanting small skin grafts and thus hastening the healing.

The Mode of Procedure in Applying a Thiersch Skin Graft to the Exenterated Mastoid Cavity.—The majority of aurists seldom, if ever, resort to the use of Thiersch skin grafts. The writer has employed them in only a very limited number of cases, as the majority of cases thoroughly operated upon seem to do as well and heal as rapidly without as with the skin graft. Some aurists apply the graft at a secondary operation some days following the primary one, while others insert the graft at once.

The graft is obtained from the patient's thigh; the operation should be done under general anæsthesia. The method of obtaining and handling the graft has already been described in an earlier volume (Vol. IV., p. 620), and the details need not be repeated here.

The mastoid wound having been prepared for the reception of the graft, the spatula upon which it rests is introduced into the wound, the edge of the graft is gradually moved over with the teasing needle from the spatula to the innermost portion of the exposed surface to be grafted, and then, while it is held in position, the spatula is gradually removed, leaving the graft in the desired position. A glass pipette, with a bulb in the centre of it for collecting the fluid, has attached to it a piece of rubber tubing. The end of the pipette is introduced under the graft while it is being placed in position, and the operator sucks on it so as to withdraw all fluids and air from under the graft and thus permit it to apply itself closely to the surface to be covered. The graft is held in position by means of small pledgets of sterile cotton dipped in subgallate of bismuth or in aristol. The edges of the mastoid wound are united and the necessary dressing is applied to the wound. A fresh dressing will have to be applied on the third or fourth day, and on every day following. At the time of the first dressing, there is likely to be considerable odor, the result of a necrosis of the superficial portions of the graft.

2. **The Meato-Mastoid Operation.**—Heath, Ballinger, and Bryant have described operations (for the cure of chronic purulent otitis media) which, while differing in minor details, are essentially the same in principle. Their claim is that in the majority of these cases the chief seat of the disease is in the mastoid antrum and adjacent cellular structures, and that if the necrosis in this vicinity is eradicated and the exposed surface of bone properly covered with an epithelial membrane, the Eustachian tube will be amply able to drain the middle-ear cavity, and that the latter, in time, unless there is necrosis of the ossicles, will resume a normal condition. The advantage of this method of operating over the radical operation lies, as they believe, in the facts that the drum membrane and the contents of the tympanic cavity are not interfered with, and that consequently the function of hearing is preserved. Indeed, in some cases, as they claim, the hearing, upon the subsidence of the disease in the middle ear, actually improves.

The operation proceeds along the same lines as those followed in the simple mastoid operation. As soon as the antrum has been opened, and after it and the aditus ad antrum have been freed from all granulations and areas of necrotic bone, and their surfaces have been smoothed down, a piece of sterile gauze is placed in the aditus ad antrum so as to prevent any bony débris or other material from falling into the middle-ear cavity. A piece of moistened gauze is also, for a similar reason, placed over the opening in the drum membrane. The posterior wall is then entirely removed as far as the annulus tympanicus. A portion of the external superior wall should also be removed at this time, so that as much room as possible may be obtained for the future treatment of the tympanic cavity and also for the purpose of securing the best possible drainage. Injury to the facial nerve is not so likely to occur as in the radical mastoid operation; nevertheless, the possibility of injuring the nerve must be kept in mind. At no time must any interference with the drum membrane and the contents of the middle ear, either by probe or otherwise, be permitted through the aditus ad antrum.

The next step is to remove any polypus or any granulation tissue that may protrude from the middle ear. If the perforation of the drum membrane is large enough, a small angular curette may be introduced for the purpose of removing any granulation tissues that may be present in the lower portion of the tympanic cavity. With a straight curette, the mouth of the Eustachian tube may be gently scraped. In these procedures extreme care must be taken to avoid dislocation of the ossicles.

The piece of gauze previously placed in the aditus ad antrum is now removed, and a specially devised cannula (Fig. 364),* with air bag attached, is inserted into the aditus ad antrum, and by means of the air bag a blast of air is blown through the tympanic cavity, for the purpose of cleansing it of all secretion. If at the same time any granulation tissue is forced through the drum membrane into the external auditory canal it should be removed. If the perforation in the drum membrane is not sufficiently large to drain the middle ear properly, the opening may be increased in size. Or, if the perforation is not well situated to afford satisfactory drainage, a new opening may be made. Following this, the tympanic cavity is washed out with a normal saline solution by attaching a syringe to the previously mentioned cannula.

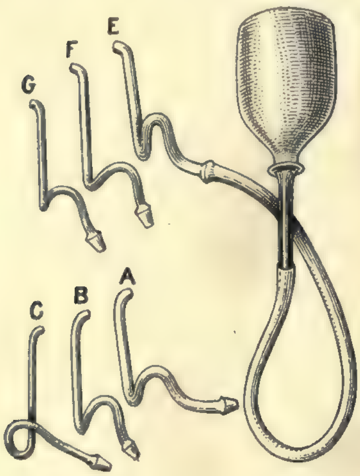

Fig. 364.—The illustration shows the cannulas devised by Heath to be inserted into the aditus ad antrum, for the purpose of forcing a blast of air through it and the tympanic cavity, with the expectation that this blast will force out of both these cavities all débris and secretions. The cannulas are made in three different sizes and are so constructed that there are rights and lefts of each of the three sizes. Attached to one of the cannulas is the air-bag that may be employed with all of them. The cannulas may also be used in washing out the cavity with sterile solutions.

The next step is to make the meatal flap according to one or other of the methods already described. In making this flap the operator should extend the incision further into the superior portion of the external auditory canal wall, so as to obtain a larger area of skin surface and at the same time more room for subsequent treatment. The flaps are sutured and held in position as described in the radical mastoid operation. The outer wound is entirely closed and the cavity packed through the meatal opening, care being taken not to press unduly upon the tympanic membrane.

After-treatment.—On the third, fourth, or fifth day following the operation, the dressings should be removed, the cavity carefully wiped out, the cannula (with air bag attached) introduced into the aditus ad antrum, and the tympanic cavity cleansed of all secretions by forcing a blast of air through it as at the time of operation. All granulations that may be found present should be removed.

After a few weeks the mastoid cavity will be covered with an epithelial lining, and the entrance from the aditus ad antrum into the tympanic cavity closed by new connective tissue. If this passage into the tympanic cavity

* These cannulas are made in three sizes for each ear (right and left).

threatens to close too early, that is, before all discharge has ceased, it should be kept open by means of a probe.

3. **The Stacke Operation.**—The patient is prepared as for the former operations. The first incision is made as in the radical operation described above. The anterior flap is reflected forward so as fully to expose the bony external auditory canal; the membranous canal is then completely shelled out of its bony support, and the entire mass is held forward with a blunt retractor. This gives an unobstructed view of the tympanic cavity and of the bony structures to be operated upon. If any remnants of the tympanic membrane or of the ossicles, or any granulation tissue, be present, they should all be removed and the tympanic cavity cleaned. As the next step, the upper and posterior walls of the canal should be removed with the chisel to such an extent as will fully expose to view the epitympanic space and the antrum. Of course, great care should be used to avoid wounding the facial nerve. As an extra precaution against the accident Stacke makes use of a hook-like instrument which he calls a "protector," and which is introduced from the tympanic cavity into the antrum, so that if by any chance the chisel should slip it will strike this protector. The posterior canal wall is removed as in the radical operation, and all cells adjacent to the antrum are removed; in fact, the operation on the bony part should, so far as circumstances will permit, be as radical as the so-called radical operation. The chief point of difference between the two is to be found in the fact that, in the radical operation, the mastoid cortex is first removed and the antrum entered from behind, while in the Stacke operation the antrum is entered from in front and the mastoid cells are excavated by work done wholly from the side of the external auditory canal—the mastoid cortex being left undisturbed. This operation must necessarily be less complete than the Schwartze-Stacke operation, for it is not possible, by way of the external auditory canal, to remove the mastoid cells at the tip, or even those situated at a higher level. Exposure of the middle or the posterior cerebral fossa often takes place in the Stacke as in the other operations, but under strict asepsis this occurrence need cause no anxiety. Stacke's, as well as the other methods of furnishing an epidermal lining for the excavation by means of a flap, has already been described above. The flap or flaps thus provided are to be pushed into place, and sterile gauze packed in upon them to hold them in apposition with the bony wall after the external mastoid wound has been entirely closed. In the subsequent management of the case the same directions are to be followed as those which are mentioned in the description of the Schwartze-Stacke operation.

So far as results are concerned, this method of operating is not so satisfactory as the radical operation, and it is seldom employed.

VIII. PLASTIC OPERATIONS FOR THE CLOSURE OF POST-AURICULAR FISTULÆ.

Cases of mastoiditis occur in which the pus forces an outlet for itself through the anterior surface of the mastoid process and causes sloughing of the posterior membranous wall of the external auditory canal. In such cases it often happens that there is left a permanent fistulous channel leading from the posterior meatal wall backward to the post-auricular groove. It is also not a rare occurrence for the mastoid flaps, after a radical mastoid operation, to fail entirely to unite. For cosmetic as well as for other reasons—*e.g.*, to prevent the intrusion of dust and other foreign substances into the canal or to prevent the too sudden and too direct impact of air upon the foot-plate of the stirrup or the membrane covering the round window—it may be necessary to close this opening by some plastic method. The closure of such an opening should not be attempted unless the

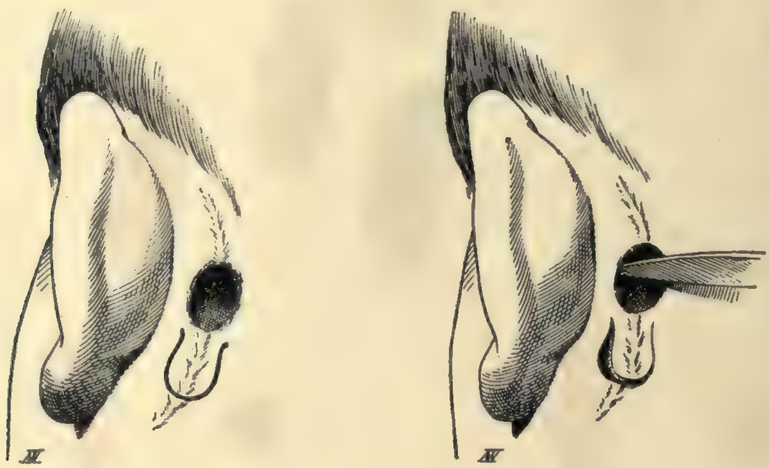

FIG. 365. FIG. 366.

FIG. 365.—Incision Employed in Forming the Flap According to the Mosetig-Moorhof Method. (Laurens.)

FIG. 366.—In this illustration the flap has already been dissected loose from its underlying attachments, and the sharp-pointed bistoury is represented as cutting the grove in the opening. (Laurens.)

cavity has been free from all evidences of inflammatory action for a period of several months.

STEPS OF THE OPERATION.—General anæsthesia is preferable; local anæsthesia should be employed only in very simple cases.

The parts, both outside the auricle and within the canal or within the excavated mastoid cavity, should be rendered sterile by washing them with tincture of green soap and then applying freely seventy-five-per-cent alcohol.

The instruments and materials needed are: a sharp-pointed bistoury, two dissecting forceps (of the mouse-tooth variety), artery clamps, probes, scissors (sharp-pointed, blunt-pointed, and curved on the flat), a needle holder, small and delicate full-curved needles, catgut No. 0, silkworm gut, and sterile-gauze dressings.

The method of operating varies with the size of opening to be closed and also with the condition of the cutaneous structures that surround the opening. When the opening is small and the surrounding skin contains no cicatricial tissue and is freely movable over the underlying bone, it is only necessary to freshen the edges by cutting, with the bistoury, a strip along the entire margin of the opening. The edges may then be united with silkworm-gut sutures. If the skin is not as freely movable upon the underlying periosteum as it should be, it may be found necessary to loosen the attachments between the two by a subcutaneous incision.

In certain cases the procedures just described do not meet the requirements, and one may then employ either the Mosetig-Moorhof or the Passow-Trautmann method.

The Mosetig-Moorhof Method.—The flap is formed by making a U-shaped incision in the skin beneath the opening to be closed. (Figs. 365 and 366.)

Fig. 368.

Fig. 367.

Fig. 369

Fig. 367.—Diagram Representing a Section through the Flap Employed in the Mosetig-Moorhof Method. The lower subcutaneous part, which projects like a ledge, is inserted into the groove or recess which is prepared for its reception in the sides of the opening behind the auricle.

Fig. 368.—The Mosetig-Moorhof Flap being Sutured in Position. (Laurens.)

Fig. 369.—Completion of the Closure of the Post-auricular Opening According to the Method of Mosetig-Moorhof. (Laurens.)

This incision should extend only through the superficial layer of skin. A second incision is made about one millimetre and a half beyond and parallel to the first. The skin lying between these two incisions is next dissected out, and the second incision is then deepened down to the level of the periosteum. Commencing along the line of the second incision the knife is used in dissecting the tongue-shaped flap, from below upward, loose from its attachments to the periosteum. The flap thus dissected free from its attachments (except at its broad base or pedicle) is wider on its under or subcutaneous surface than on its outer or epidermal surface because of the narrow rim or ledge of denuded tissue which surrounds it. (Fig. 367.) The next step is to incise, with a sharp-pointed bistoury, a groove, 2 or 3 mm. in depth, all around the upper two-thirds of the opening (Fig. 366) and at a short distance (in depth) from its margin. The tongue-shaped flap is then inverted into the opening and its ledge-like margin is inserted into the groove prepared for its reception, in much the same manner as a watch crystal is held in its rim. Four or more rather long sutures are used for holding the flap in position. These sutures should be passed through the flap before it is inverted, and special care should be taken to carry them through the cutaneous part of the flap. (Fig. 368.) The cutaneous surface of the flap, in its new position, faces inward or toward the region of the middle ear. The raw or external surface of the flap may be covered with a Thiersch skin graft or it may be allowed to heal by the process of granulation from the edges. The edges of the lower wound from which the flap was taken are brought together by suturing. (Fig. 369.) A similar operation may be done by borrowing the flap from the posterior surface of the auricle.

The Passow-Trautmann Method.—Two vertical incisions, 2 or 3 mm. in length, are made through the skin and subcutaneous tissues into the cavity of the mastoid in the longitudinal axis of the opening—one above and the other below it. The outer ends of these incisions are joined by an anterior and a posterior semicircular incision, both of which are parallel to the margins of the opening. The posterior incision is carried through to the periosteum, and the anterior one to the perichondrium. The flaps outlined by these incisions are dissected up from the underlying tissues so as to form an anterior and a posterior flap. Care must be taken not to cut through at the margin of the opening. The flaps are then inverted into the opening and are united, one to the other, by means of sutures introduced longitudinally through each flap. Finally, the margins of the external wound are united. It may be necessary, because of undue tension, to loosen the skin covering the mastoid process before the margins of the wound can be approximated.

In all these operations there will have to be both an external dressing of sterile gauze and an internal one placed within the cavity. On the sixth or seventh day the dressings may be changed and the sutures removed.

SINUS THROMBOSIS OF OTITIC ORIGIN, AND SUPPURATIVE DISEASE OF THE LABYRINTH.

By JOHN D. RICHARDS, M.D., New York City.

I. SINUS THROMBOSIS.

Etiology.—Infective thrombosis of the intracranial sinuses occurs, as a rule, in adults, often in children, rarely in old age. It is most commonly associated with chronic suppurative middle-ear and mastoid disease, though frequently it arises in the course of acute inflammation of these structures. As there are comparatively few old people with chronic suppurative middle-ear disease, the condition is not often met with in this class; and, as the vascular connection between the middle ear, the mastoid, and the intracranial cavities is in children intimate, meningitis is the more common complication in the infant. Age confers no immunity.

Infective thrombosis may also arise from infected scalp wounds, from fractures of the skull, from erysipelas, or from suppurative disease of the sphenoidal sinus, the pus travelling by way of the cavernous sinus. In fact, it may arise from any one of a great variety of suppurative processes about the head. In the vast majority of cases, however, the thrombosis owes its origin to suppurative ear disease.

Anatomical Relations and Pathology.—The portion of the intracranial system of venous sinuses which becomes primarily involved from the extension of suppurative ear disease is that which lies in immediate contact with the mastoid and petrous portions of the temporal bone, viz., those venous channels which are known as the sigmoid sinus with its emissary and tributary veins, the inferior and superior petrosals, and the jugular bulb. While the lateral sinus and the jugular vein with its tributaries are frequently involved, they become so, as a rule, from extension of the thrombo-phlebitis from the sigmoid and superior petrosal sinuses, on the one hand, and from the jugular bulb and the inferior petrosal sinus, on the other. Primary thrombosis of the jugular vein resulting from ear disease is practically unknown. Though the lateral sinus may become involved primarily at its junction with the sigmoid—*i.e.*, at the knee,—the major portion of this sinus is not in close anatomical relation to the suppurating middle-ear and mastoid cavities. The lateral sinus, however, is intimately related to the blood channels of the labyrinth and a primary involvement of the former may occur when the labyrinth is the seat of a suppurative process.

Infection of the sinus system takes place, as a rule, in one of the following ways:—First, by direct extension of the purulent process from the mastoid cells by contiguity; *i.e.*, the sigmoid-sinus groove is eroded, the sinus is exposed to the direct action of the suppurative process, and thrombo-phlebitis ensues. Second, the sinus system is invaded by the transmission of infective agents from the middle ear, the labyrinth, or the mastoid cavities, along the minute vessels which traverse these structures and which empty into the sinus system. In this connection may be mentioned several systems of minute blood-vessels which are of extreme importance:—

(*a*) A leash of minute veins which arise from the mastoid antrum and middle-ear cavities. These veins pass outward in the bony angle included between the knee of the sigmoid-sinus groove and the under surface of the middle cranial fossa, and empty into the sinus at its knee, *i.e.*, at its junction with the lateral sinus. This explains the frequency with which the sinus is thrombosed at this point.

(*b*) A minute set of veins which pass downward from the mastoid aditus ad antrum over the posterior semicircular canal into the deep horizontal limb of the sigmoid sinus.

(*c*) Vessels which communicate between the labyrinth and the sinus system. Veins of the vestibule and the semicircular canal system communicate with the lateral sinus, those of the cochlea with the inferior petrosal. This explains the frequent association of infective sinus thrombosis and suppurative inflammation of the labyrinth.

(*d*) In addition to the above, innumerable small blood-vessels may be seen traversing the muco-periosteum which lines the mastoid cells. Many of these perforate the bony shell of the sigmoid sinus and empty into the contained vein at different levels of its course through the temporal bone, and it is along these avenues that infection may be transmitted from any portion of the diseased mastoid to the sinus.

An important clinical difference exists between the thrombo-phlebitis which originates by an extension of a purulent inflammation along the minute vessels, and that which results through a direct extension of such an inflammation, by contiguity, from an adjoining structure; the essential difference between the two being that the first is, as a rule, the more formidable.

In infective thrombo-phlebitis both the sinus wall and the thrombus may present a variety of appearances which depend upon the degree of inflammation of the vein and the stage of disintegration of the clot. The vein may show, in different cases, all stages of phlebitis, and the contained thrombi may be found in all stages of disintegration. The vessel may be covered with a thick layer of large black disintegrating granulations; it may be softened and infiltrated or even ulcerated through at the site of the thrombus. Again, there may be no granulations on the outer surface of the vein, and its color may be that of pus, or it may be invested with a layer of yellow exudate. In some instances there may be found spots where the vessel is covered with a greenish-yellow or black necrotic dura. This latter appearance is commonly found in the thrombo-phlebitis which originates from chronic purulent middle-ear disease, and is often associated with a collection of pus between the sinus and the skull

—*i.e.*, an extradural abscess surrounding the sinus. The thrombus, if recent, may appear as a liver-colored coagulum loosely adherent to the inner wall of the sinus; later, it may be blackish in color, with small yellow purulent foci scattered through it, and it may emit a foul odor; or it may have undergone liquefaction and be represented merely by a collection of pus.

When, through erosion of the surrounding shell of bone, the vein itself is exposed to the suppurative process and a thrombo-phlebitis results, an inflammatory reaction frequently develops in it: granulations invest its walls, and the vessel becomes sealed on that side of the skull which surrounds the margin of the hiatus; its walls thicken; it loses its endothelium; and the clot which at first was parietal and did not completely fill the lumen becomes firmly adherent to the vein so that it is difficult to detect the line of demarcation between thrombus and vessel wall. As the inflammatory process augments, the thrombus becomes obstructive. Both at the proximal and at the distal end of the original clot, the blood in the vessel coagulates, and the superimposed clotting may extend backward so as to involve the lateral sinus and a great portion of the sinus system. It is in this way that very extensive thrombosis occurs. Again, the thrombus may extend downward into the jugular bulb and from thence into the vein, causing extensive thrombosis in the branches of the jugular tree. Under the peptonizing action of bacteria the clot may disintegrate and liquefy. The walls of the sinus at the original site of the thrombus may ulcerate and the purulent contents at this point may be emptied into the cavity of the mastoid. If the clots at the proximal and distal ends of the disintegrating thrombus remain uninvaded by bacteria, they act in a protective manner, preventing the dissemination of septic particles throughout the circulation. Should the clot, however, undergo disintegration, particularly at its cardiac end, the infective material may readily pass into the general blood stream through the avenue of the jugular and be distributed throughout the system. Occasionally the thrombus liquefies and the current passes again through the thrombosed vessel, sweeping the disintegrating septic material into the circulation with resulting metastatic deposits.

There are several ways in which the septic material may gain access to the general circulation:—

1. Through the great avenues of the jugular and its tributaries.

2. Through the emissary and tributary vessels of the sinus and jugular bulb. (It should be remembered that the blood currents in these vessels may become reversed under the condition of disturbed circulation incident to thrombosis.)

3. Infection may pass through the vessel wall into the adjacent tissues and be taken up into the general circulation from the perivascular spaces. This is especially well seen when the jugular vein becomes involved in the thrombotic process. The tissues adjacent to the jugular undergo inflammatory infiltration, exudation occurs, and the neck becomes tender and brawny along the course of the vein. The lymph nodes enlarge and soften, or break down and suppurate. The jugular becomes soldered by plastic exudate to the surrounding

structures, so that it is difficult or impossible to exsect it. The common sheath may become greatly thickened.

Symptomatology.—The symptoms may be attributed, as a rule, to one of several causes:—(1) To circulatory disturbances incident to obstruction of the main sinus and its tributary and emissary vessels by the thrombus; (2) to the local inflammatory process in the sinus and the adjacent structures—an inflammation which owes its origin to the middle-ear suppuration; (3) to the dissemination of infective agents throughout the general system.

Cephalalgia is an early symptom. It is usually worse at night and is generally referred to the involved area, from which it radiates over the corresponding side of the head. There may also be *vertigo* and *vomiting*, although these symptoms are more common when an associated meningitis is present.

Chills, fever, and *sweats* occur. These three associated symptoms form a group indicative of septic absorption, and consequently appear upon the disintegration of the clot and its distribution throughout the general circulation. They therefore occur irregularly and repeat themselves throughout the course of the disease; and they vary in intensity with the amount and nature of the septic material thrown into the circulation at a given time. There may be severe rigors or merely chilly sensations. In infants the rigors may be mistaken for convulsions. The fever which accompanies the chill rises rapidly to the extent of from three to six degrees and then suddenly declines. A profuse sweat follows. As the disease progresses and the system becomes more profoundly septic, the fever shows a tendency to become remittent. Later, the facies indicative of sepsis appears. The tongue is thickly furred and the breath heavy or fetid. The pulse is rapid, soft, and thready; it retains its rapidity during the intermissions or remissions of fever and is the most stable guide to the general septic condition. Upon the lodgment of septic emboli in the lungs, cough and pleuritic pain appear, followed by the other symptoms of septic pneumonia or of gangrene, with foul expectoration. Septic enteritis with fetid diarrhœa may develop. The mind remains clear, as a rule, in uncomplicated cases, though there is occasionally a tendency to marked drowsiness.

Chill, remitting temperature, and sweating, while not infrequently the earliest symptoms through which the disease announces its presence, must, in the light of their pathological import (inasmuch as they signify clot disintegration and not thrombus formation), be regarded as later manifestations proclaiming the advent of sepsis.

When the thrombosis involves the deep portion of the sigmoid sinus, œdema of the skin behind the mastoid tip is frequently observed. Over the course of the jugular there may be marked tenderness; this is usually confined, however, to the upper third of the vessel and is due to the swollen lymph nodes which participate in the inflammatory process. A cord-like swelling over the course of the jugular is rarely detected. Even when this vessel is occluded by a firm obstructive clot it is not, as a rule, possible to detect the condition by palpation, owing to the inflammatory œdema of the adjacent tissues. To relieve the tension of the skin over the inflamed tissues of the mastoid and neck the patient may hold the head in a position of torticollis.

Neuro-retinitis or choked disc may be observed in either eye; it occurs most commonly in those cases in which the jugular bulb is thrombosed, with damming back of the current of the inferior petrosal upon the cavernous sinus and the ophthalmic veins. It occurs in about ten per cent of the cases.

The blood shows the changes incident to sepsis. There is usually an increase in the leucocytes and in the relative percentage of polymorpho-nuclear neutrophiles.

Diagnosis.—When, in the course of acute or chronic middle-ear and mastoid disease, there occur repeated chills, elevation of body temperature with sudden fluctuations of from three to six degrees, followed by profuse sweating, the condition of infective sinus thrombosis should be regarded imminent.

From malaria the condition is differentiated by the blood examination. Frequently in sinus thrombosis the blood shows those changes in the relative proportion of its cellular constituents which are incident to the absorption of pus. From purulent leptomeningitis the condition is often difficult to diagnose, and the two are frequently associated. In meningitis there are apt to be stiffness of neck, marked irritability, hebetude or delirium, and strabismus; and the fever is usually high, showing fluctuations which are not so great as those which are seen in thrombosis. Vomiting and vertigo also occur more frequently. Koenig's sign is often present in meningitis and is of considerable diagnostic importance. Furthermore, the pulse in this disease is extremely variable in its rapidity, as are also the respirations. By lumbar puncture the diagnosis may often be definitely established. In meningitis the fluid may show not only turbidity and shreds upon deposit, but also the presence of pyogenic organisms. From uncomplicated brain abscess the condition is more easily differentiated. Following operation upon the mastoid many of these symptoms appear upon the development of erysipelas. An inspection of the wound, however, often determines the cause of the manifestations.

Occasionally infective sinus thrombosis (owing to the lodgment of an infective embolus in the lung) commences with the clinical picture of circumscribed pneumonia. An initial rigor occurs; the temperature rises rapidly to 104° F. or 106° F., and may remain at this level without remission for some days; there is pleuritic pain, with cough and bloody expectoration, and the respiratory movements are more rapid than normal. In addition to these symptoms the physical signs of circumscribed pneumonia may be present. In a few days, however, the true septic condition of the pneumonic process becomes apparent. The bloody expectoration changes perhaps to foul prune-juice fluid, fluctuations in the temperature appear, and the pneumonic area, as shown by the physical signs, does not extend as it commonly does in the ordinary frank lobar pneumonia.

Even after the sinus has been exposed to view, the diagnosis of thrombosis may be attended with difficulties. The symptoms may have pointed to thrombosis, and yet the vessel, when thus exposed, may not show sufficient change in its physical appearance to corroborate such a diagnosis. Again, during the mastoid operation we frequently expose a sinus which appears thrombosed, and yet there have been no symptoms which would indicate such a condition. As it is only by opening the sinus that we can definitely determine its condition, and as an error in diagnosis or a delay in operating in suspected cases is so frequently followed by a fatal result, the safest procedure, when one is in doubt, is to open the vessel for exploratory purposes. Experience has taught us that the appearance of the sinus and the sensations which it conveys to the examining finger are not altogether reliable guides as to the vein's involvement; and I might add that many have not as yet sufficiently awakened to the insidious and formidable character of this disease, nor to the fact that in the earliest part of sinus thrombosis the disease is silent and does not manifest itself through symptoms indicative of its presence.

If the parts have been properly cleansed it seldom happens that harmful results follow from opening the vessel; and in any event the danger is remote as compared to that which we incur when we fail to explore a vessel in which a thrombus is present. Failure to explore means that in quite a number of instances we shall leave behind in these sinuses thrombi the presence of which is not revealed until the disease later announces itself through symptoms—that is, at a time when operative interference will often fail to prevent a fatal termination.

When sinus thrombosis has passed into the stage in which it manifests itself through symptoms indicative of sepsis, it has then become formidable, and a large proportion of these patients die regardless of surgical interference. It is imperative, therefore, that we do not remain in doubt as to the vein's involvement.

Complications.—As a result of softening and infiltration of the inner wall of the lateral or sigmoid sinus, or through an extension of the disease to the intracranial structures, a cerebellar or a cerebral abscess may develop. More commonly, however, the result is a diffuse purulent lepto-meningitis. Upon the dissemination of septic emboli throughout the system, the lungs, the joints, the subcutaneous tissues, the liver, the spleen, the kidneys, etc., may become the seat of metastatic abscesses. A general invasion of the blood by pyogenic bacteria may follow, the patient then dying of gradual exhaustion accompanied by irregular fever, chills, sweats, and exhausting diarrhœa. The lungs are the most frequent site of metastatic deposits, and septic pneumonia, abscess, or gangrene, with foul-smelling expectoration, often terminates the case. Associated with purulent thrombosis of the sigmoid sinus, there is often found, between the skull and the vein, a collection of pus (an extradural abscess). As this abscess enlarges it separates the dura from the skull and may cause occlusion of the sinus. Frequently this abscess is foul-smelling, and, when this condition is found, it may be assumed that some intracranial complication (infective sinus thrombosis, brain abscess, or meningitis) is present. Such a collection of pus may find exit from the skull through the foramina of the mastoid emissary and posterior condylar veins and cause induration or deep abscess in the tissues of the neck.

Technique of the Operation for Exploring the Sigmoid and the Accessory Sinuses.—*Exposure of the Groove-like Shell of Bone in which Lies the Sinus.*—As infective sinus thrombosis of otitic origin is, with rare exceptions, secondary to mastoid involvement, the exploration of the mastoid and the removal of its septic foci constitute the primary step of the sinus operation. (These preliminary steps will be found in the section on Mastoiditis, in the preceding article.) We approach the sinus through the mastoid wound, after having exposed the shell of bone in which lies the sinus. The surgeon should be careful not to waste valuable time on this preliminary work, for it may become necessary to explore the lateral and superior petrosal sinuses and the bulb of the jugular or to resect the jugular vein. In removing the mastoid, therefore, the attempt should be made to remove its septic foci as quickly as possible without indulging in the niceties of a classical operation, for shock may overtake the patient before we have terminated the crucial part of the procedure—*i.e.*, the exploration of the sinus system.

Exposure of the Sinus.—Having laid bare the shell of bone in which lies the sigmoid sinus, we next expose the latter structure by removing a portion of the shell, at a point slightly below the knee of the sinus. But if a hiatus (the result of erosion) is found to exist in a certain part of the shell, the work of removal may commence at this point. This work is best accomplished either by the use of the chisel and mallet (the stroke of the chisel being directed toward the tip of the mastoid, in the long axis of the bony groove and almost tangentially to it) or by shaving down the bony shell, with a broad-nosed sharp-edged curette, until the dura of the sinus is exposed. The advantage possessed by the chisel manifests itself in the greater rapidity with which the work advances, while that possessed by the curette is to be found in the fact that it does not cause jarring of the clot within the sinus and therefore avoids the danger that a loosely clinging portion might be set loose in the circulation.

The Separation of the Sinus from the Surrounding Groove-like Shell of Bone.—A small area of the sinus wall having now been exposed, a separator (a grooved director, the flat end of a probe, or a small curette will equally well serve the purpose) is introduced between the dura of the sinus and its surrounding shell of bone, and the two are separated as far as can be accomplished safely. Next, a, rongeur with suitable blades (a broad-nosed rongeur is safest) is employed for removing such portions of the bony groove and immediately adjacent skull as have been loosened from their attachments. One should remove all those portions of the skull which are no longer in a healthy condition.

In separating the sinus at its knee from the shell of bone in which it lies, great care must be exercised to avoid tearing the wall of the vessel, for at this point the sinus is noticeably adherent to the bone, being anchored to it by the leash of minute vessels previously referred to as coming from the antrum, passing through the shell of bone, and then entering the vein.

The Extent to which It Is Desirable to Expose the Wall of the Sinus.—It is scarcely possible to state in a definite manner the length of the area throughout which the sinus should in all cases be exposed. We cannot be governed by an arbitrary rule in work of this nature. The statement may be made, however, that it is better to expose too great a length of vessel wall than too little. There is no one error which contributes more to improper technique, which causes important pathological conditions to be so frequently overlooked, or which results so often in unnecessary loss of blood—a loss which the patient can ill afford—as that of exposing too small an area of sinus wall. The lack of adequate space not only renders manipulation of the vessel extremely difficult, but it also pre-

FIG. 370.—In this illustration are shown the primary incisions requisite for the exploration of the mastoid apophysis and the sigmoid sinus. (Original.)

vents the operator from exploring the vessel in such a way that he may draw definite conclusions as to the nature and extent of the pathological changes. (Figs. 370-374.)

The important indications to be met are the following:—

(*a*) Healthy sinus wall and dura (that, namely, which is not covered with granulations and which is not discolored) should be reached on both the torcular and the bulb sides of the involved area. In certain instances of extensive involvement the pachymeningitis may extend so far down toward the bulb that it is impossible to expose the limit of diseased dura. When possible, however, this limit should always be reached.

(*b*) The area of exposure should be sufficiently large not to hinder manipulation of the sinus.

(*c*) This area should embrace that portion of the sinus into which the mastoid emissary vein and the superior petrosal sinus enter, for, when the attempt is made—in testing the patency of the sinus—to determine the source from which the return flow of blood comes, these vessels may act as factors that are capable of falsifying our conclusions.

(*d*) The conditions above mentioned necessitate, as a rule, a minimum exposure of the sinus from a point half an inch beyond the knee out upon the lateral sinus, to a point well down toward the jugular bulb—*i.e.*, over an area which measures something over two inches in length. It may of course be necessary, when the lateral sinus is extensively involved, to uncover this vessel backward as far as the torcular.

(*e*) The full width of the sinus and at least a slight strip of dura, both anteriorly and posteriorly to the sigmoid, as well as above and below the lateral sinus, should always be exposed throughout the entire length of the area of vessel wall laid bare. At the upper and lower limits of this area the vessel should be separated from the overlying skull for a short distance beyond, to allow for the insertion of compression plugs between the sinus and skull (for the purpose of controlling hemorrhage). This control is brought about by the intracranial pressure which forces the sinus against the plug and skull and thus causes oblit-

FIG. 371.—This figure illustrates the method of opening the mastoid apophysis by a groove which hugs the posterior wall of the external auditory canal, and which extends from the suprameatal triangle to the mastoid tip. (Original.)

eration of the lumen of the vessel. For this reason low intracranial tension augments the tendency to bleeding.

Opening the Sinus.—The vessel having been exposed and palpated, to determine if there is any point along its course where it seems likely to be thrombosed, an opening is made in its wall. Frequently the site of the thrombus is evident. When this is not the case, the opening should be made at that point in the suspicious area which is most convenient. Generally, this point is found just below the knee of the sigmoid sinus.

A small cylinder of gauze is placed across the bulb end of the sinus, but the vessel is not compressed; and a second cylinder of gauze is similarly placed on the torcular side of the point which has been selected for opening the sinus and at a convenient distance from it. The opening is best made with the point of a sharp scalpel, the cutting being done from above downward,—*i.e.*, from the knee of the sinus toward the bulb,—while the back of the knife is held toward the vessel. Care is taken not to cut through the inner sinus wall. Should free bleeding occur, the operator compresses the plug on the torcular side, thus blocking the flow from above. If the bleeding is still free, the assistant quickly blocks the return flow from below by compressing the lower plug. If the bleeding continues, we should remember that the emissary vein may be responsible; and

FIG. 372.—This figure is intended to show the interior of the mastoid apophysis with its cellular spaces, and just above these, to the left, the floor of the midcranial fossa. (Original.)

hence the importance of previously exposing this vessel's point of exit from the sinus.

If we obtain a return flow from below, before exerting pressure over the bulb end of the sinus, we minimize the chances of producing unnecessary pressure upon a vessel which is thrombosed, and therefore of discharging emboli into the general circulation. By opening the sinus before producing pressure upon the torcular side of the point of incision, we create an avenue of exit for any portion of a clot which, by our manipulation, may be set loose.

With the compression plugs in place, the opening in the vein may be enlarged with the scissors and its interior carefully inspected.

(*a*) If the examination should reveal that there was nothing abnormal in the sinus, we may proceed to investigate the region of the bulb and the superior petrosal sinus.

If we have reason to fear that a small parietal thrombus is lodged in the region of the bulb, not sufficiently obstructive to diminish noticeably the return flow from below, we may proceed in the following manner:—A bent curette is introduced into the sinus at the site of the lower compression plug. An assistant now makes firm pressure over both internal jugulars (low down in the neck). The lower gauze plug is then removed, and such curetting as can be done is rapidly accomplished, in the hope that the thrombus, if such exists, has been dislodged. The curette is quickly withdrawn, and the hemorrhage is controlled by the lower compression plug, after which pressure in the neck is released. By producing pressure over both internal jugulars we eliminate to a great extent the aspiratory influence of inspiration, lessening thereby the chances of emboli passing into

FIG. 373.—The manner in which the mastoid tip is removed is shown in this figure. (Original.)

the general system. At the same time the backward flow through the sinus wound is materially increased, thus giving the septic particles, if such are present, a better opportunity to be extruded. If we knew positively that a clot was within the bulb, it would not be permissible to make an attempt to dislodge it prior to a jugular resection; but the procedure described above refers to those cases in which the presence of a clot within the bulb is problematical, and in which the evidence is not sufficient to warrant the making of a jugular resection. Cases of this nature are occasionally observed.

When the symptoms of sinus thrombosis are present, this does not necessarily mean that the sigmoid sinus is the vessel involved, although from the extension of otitic disease it is the sinus which most commonly suffers. The sigmoid may appear perfectly normal in all respects, and if, after opening this vessel, we find that it presents no evidences of disease, we should suspect that possibly the superior petrosal sinus is the vessel involved, especially as this sinus stands in close anatomical relationship with the field of original infection. Our next step, therefore, should be to remove the groove-like shell of bone in which the sigmoid sinus lies, up to and slightly beyond the knee, block the flow from the torcular end, and test the patency of the superior petrosal. This vessel is of such small size that if thrombosed it quickly becomes completely blocked, and therefore a return flow from it is good evidence that this sinus is not invaded. We can determine this without opening it, by merely observing the return flow of the blood into the sigmoid at the point where the smaller sinus enters the larger. When the superior petrosal is being tested the emissary vein should be obliterated, as it may enter as a factor of error in determining the source of the return flow.

Fig. 374.—In this figure are shown the various structures which are exposed to view when the removal of bone from the mastoid process is carried to a greater depth than was done in any of the instances represented in the preceding figures. In the central part of the picture may be seen the three semicircular canals—the superior above, the external below and to the left, and the posterior below and to the right. In the dark triangular space to the left of the superior semicircular canal may be seen the horizontal limb of the incus, resting upon the floor of the aditus. The sac-like object seen below and on the right side is the thin shell of dense bone which covers the vertical limb of the sigmoid sinus. (Original.)

(*b*) If after opening the vein (the sigmoid sinus) (Fig. 375) we get but little bleeding we may be sure that we have opened a vessel which is involved in partial thrombosis. If the bleeding is not sufficient to be annoying, no compression need be made, or the upper end of the sinus may be obliterated if desired. With the scissors, the lower end of the sinus is slit freely open, and, as the incision is carried down into the healthy vessel wall toward the bulb, and the lower limit of thrombosis is passed, a free gush of blood will occur, after which compression should be made. The upper end of the sinus may later be slit open with scissors, the incision passing outward until the upper limit of the thrombotic process has been reached, when compression may be made to control the hemorrhage from the torcular end. The diseased parietal wall of the vein is removed with scissors, and the interior of the vessel is inspected.

If, after getting a free return flow from either side and placing the compression plug, we find, upon examination, that the vein is involved at that point, we should continue to remove the surrounding bony shell, should place a second compression plug on the distal side of the first, should remove the first plug,

FIG. 375.—The Sigmoid Sinus and a Portion of Its Extension, the Lateral Sinus, are shown in the upper part of the picture. The external wall of the vessel has been opened at the "knee"—*i.e.*, at the point where the lateral sinus joins the sigmoid. In the lower part of the picture is shown the jugular vein with its chief branches. The divided ends of the omo-hyoid muscle may also be seen near the lower end of the incision. (Original.)

should slit the wall of the vein up to the distal plug, and so on, until the upper and lower limits of invasion have been passed.

(*c*) If, after opening the sinus, we get no return flow, the vessel is either occluded by an obstructive clot or is collapsed. We select the upper end of the vein, and with scissors slit its external wall up toward the knee, and, if necessary, out on the lateral sinus, until the incision has passed the upper limit of thrombotic involvement, when a free return flow from the torcular end will occur. Compression is now made.

We should not introduce a curette and attempt to dislodge the thrombus from the distal end, for we are dealing not only with an infective thrombus, but with an infected vessel also, and this septic tube must be freely opened beyond the limit of its invasion, otherwise we leave behind the essential factors for a reinfection. The infected wall collapses and is held in contact with the visceral wall by the compression plug; this blocks drainage from the infected tube—a focus from which meningitis may proceed. The frequency with which a meningitis is grafted upon a sinus thrombosis should make us consider the manner in which the extension occurs. Copious return flow is no guarantee of safety under these conditions, for the infected vessel is a factor; it bears to the thrombus the relation of cause. If, instead of slitting this infected tube wide open and exsecting it, we should merely curette its interior sufficiently to establish a return flow, such a procedure would rightly be considered not only bad surgery, but also, owing to the proximity of the endocranial lymph sac, an extremely dangerous practice.

The lower portion of the sinus is next treated in the same manner as was recommended above for the upper portion, and if it be found that the incision extends below the lower limit of the thrombosis and that the clot does not extend into the bulb, the free return flow from the bulb end of the sinus is permanently controlled. Lastly, the diseased parietal wall of the vein included between the two compression plugs should be removed.

When the sinus is opened great care should be taken to avoid cutting through the visceral wall. This is not an altogether uncommon accident and is a particularly unfortunate one in the young. We not only open the subdural space and invite infection, but in children, whose intracranial pressure is subject to sudden increase, as during the act of crying, the danger of cerebral hernia is not remote.

(*d*) If, after the vessel has been slit freely open as far down toward the bulb as the removal of bone substance permits, we get no spontaneous return flow or an insufficient flow from below, and if, furthermore, we are unable to pass the lower limit of thrombosis, we should immediately proceed with a jugular resection and should make no attempt to curette the thrombus from the bulb before the vein shall have been removed.

In view of the fact that the latter procedure is so generally advocated, we deem it desirable to mention some of the dangers incident to its attempt. They are as follows:—

(α) It is rarely possible, as may readily be demonstrated in the postmortem room, to curette the jugular bulb.

(β) Even though we may remove the clot, the infected vessel wall adjacent to it is a surgical factor with which we have to deal. It reinfects the current, in due time a second thrombus forms at the site of the first and we are obliged to resect the jugular in order to shut off, as effectually as possible, this septic focus from the general circulation.

(γ) In removing the clot from the deep bulb end of the sinus it may break off below the point of exit of the posterior condylar vein. The re-establishment of a return flow from the bulb end under these circumstances might readily be interpreted as indicating that the entire clot had been extruded and that the jugular vein was free; whereas, as a matter of fact, the bulb below the point of exit of the condylar and the jugular vein might both be blocked by a septic thrombus.

(δ) When the deep horizontal limb of the sinus is blocked and the jugular vein is patulous, the ideal hydraulic conditions exist for the aspiration of the clot after it has been broken up by the curette into particles of various sizes.

(ϵ) The clinical evidence condemns the practice of restricting our interference to a mere attempt at curetting the bulb. The majority of cases so treated succumb to sepsis; a large percentage of those that recover develop metastases, thus showing the inefficiency of the surgical steps taken for the purpose of isolating the original focus.

The Question of Preliminary Jugular Ligation when Evidences of Aspiration of the Sinus Are Observed.—On exposing the sinus we occasionally notice a dimpling of its parietal wall during the inspiratory act. When such an evidence of aspiration of the sinus is observed, the important practical question immediately arises as to whether ligation of the jugular should or should not be resorted to before the sinus is opened; the object of such ligation being to eliminate as far as possible the danger of air embolism. Many operators answer this in the affirmative. If we adopt such a rule for our guidance we shall in many instances ligate a jugular which is in no way involved, and for no other purpose than to overcome a mechanical difficulty which it may be possible to remove by simpler means.

When the external wall of the sinus dimples it does not necessarily indicate the position of the clot; the obstruction may be either on the torcular or on the bulb side of the point which dimples, more probably on the torcular side. Moreover, the dimpling does not indicate whether the thrombus is partial or complete; it may be either. It is necessary, however, that the clot be highly obstructive. When aspiration of the sinus is observed, we should at once expose a considerable length of the vessel wall. A point is now selected on the torcular side of the part which dimples, and by pressure with the finger the lumen of the sinus is obliterated. At the same time we notice whether or not this influences the aspiration of the vessel. If, under these conditions, the sinus dimples as before, the thrombus is on the torcular side of the dimpling-point. In carrying out this procedure it is necessary to pay attention to three factors:—

(1) The point at which pressure is made should be at a sufficient distance from the point which dimples to prevent traction being transmitted along the external vessel wall to that point; for the traction, by causing the vessel wall to stretch, would affect the phenomenon.

(2) The emissary vein should be temporarily obliterated.

(3) The point at which pressure is made upon the main sinus should be, if possible, below the point of entrance of the superior petrosal into the sigmoid.

We should next endeavor to ascertain whether the vacuum can be overcome. To determine this we exert pressure, low down in the neck, over both internal jugulars, and lower the patient's head. If, under these conditions, the sinus fills and the dimpling disappears, we can proceed as under ordinary conditions of thrombosis, for the intravenous relations are temporarily restored. With pressure still continued we can with safety open the sinus, slit the external wall with scissors down toward the bulb as far as the vessel involvement may indicate, judge the copiousness of the return flow, and, if this seems normal and if the lower limit of vessel involvement has been passed, a compression plug may be placed over the bulb end and resection of the jugular avoided.

The external wall of the torcular end of the sinus may next be slit open, the incision being carried out into perfectly healthy vessel wall, beyond the limit of thrombosis. Afterward, compression should be made.

To perform a jugular resection immediately upon observing aspiration of the sinus is a hasty procedure, for aspiration may occur not only through the direct avenue of the jugular of the same side, but also through the indirect avenue of the opposite jugular. It is extremely important, from a surgical standpoint, not to regard the intracranial venous sinuses as distinct vessels, but as portions of a common circuit. The greatest length attributable to any individual sinus, surgically speaking, should be that portion of the vessel which is included between the two nearest consecutive branches of sufficient size to transmit the influence of aspiration.

Indications for Primary Resection of the Jugular.—(*a*) If, in addition to symptoms pointing to sinus thrombosis, we find, along the course of the internal jugular, induration, tenderness, and a cord-like swelling of the vessel, primary removal of the vein is indicated. It is necessary, however, to differentiate this condition from a Bezold perforation complicating mastoid disease and associated with symptoms of septic absorption.

(*b*) When, in addition to symptoms pointing to sinus thrombosis, the phenomenon of metastasis is present, primary resection of the vein should be done. The indications mentioned above are both rare.

(*c*) When the patient's condition is so grave that sufficient time cannot be found for the performance of a complete operation, we should first perform the most essential single step of the procedure, viz., the resection of the jugular.

Object of the Operation of Resecting the Jugular.—The operation of jugular resection is under certain conditions a most rational and beneficent precedure. It is a logical imitation of the process of thrombosis, the example set by Nature in her effort to interpose a protective barrier between the invader and the invaded; it is the picture of defensive warfare.

(1) The primary object of resection of the jugular is to cut off the great avenue by which septic emboli enter the general circulation.

(2) The influence of aspiration upon the broken-down particles which we dislodge in the attempt to curette the bulb end of the sinus is in great part eliminated.

(3) We cause a sudden tendency to stagnation in the multitudinous branches

of the jugular tree and bulb, with the result that we take the primary step toward interposing between the area of infection and the general system numerous non-infective coaguli, which hem in the involved area and tend to localize it. For this reason we resect the jugular instead of ligating it, and remove the vein low down in the neck, and not high up. Otherwise a collateral circulation might be established which would thwart this protective coagulation in the tributaries —a process which we desire.

Steps in the Operation for Resection of the Jugular.—An incision is made along the anterior border of the sterno-mastoid muscle from the level of the angle of the jaw to within an inch and a half of the sterno-clavicular joint. The superficial tissues down to the muscle are divided. The fascia is next incised and the muscle retracted. In exposing the vein we should first ligate it low down in the neck. By ligating early we tend to block the avenue of entrance to particles which, in the manipulation necessary to expose the vessel in its entire course, may be set loose. In the lower portion of the neck the omo-hyoid muscle, lying as it does immediately over it, is an excellent guide to the vein. This muscle is now divided. With thumb forceps the common sheath of the vein is opened, and the jugular separated from it. The vein is now ligated at two separate points and divided between the ligatures. The lower end retracts. The upper end should be seized with an artery clamp, which serves as a convenient means of holding the vessel. With a pair of tapering, blunt-nosed, curved scissors, introduced closed from below upward between the vein and its sheath, and moved slightly from side to side, these two structures are readily separated throughout the greater portion of the vessel's course. With the vein depressed and the sheath lifted, the entire thickness of the superimposed tissues may be quickly and safely divided with scissors. The larger tributaries to the jugular should now be ligated at two points and incised between. If thrombosed, they should be followed up and ligated beyond the point of thrombosis. If this is impossible, the vessels should be resected as far as can be, but no ligatures should be placed. If the upper portion of the jugular is thrombosed, no ligature is necessary, and the vessel is simply cut across with scissors; but, if the upper portion of the vein contains blood, this end is ligated. The wound is next packed and treated as an open wound. Later, the neck incision may be drawn together by strips of adhesive plaster.

In sterilizing the field of operation, it is necessary, inasmuch as we do not know what may be the condition of the interior of the jugular (it may be occupied by a disintegrating thrombus), to avoid with special care any kneading of the neck. It is best to grasp the skin and lift it from the underlying tissues, and such scrubbing as may be thought desirable should be done without pressure.

The branches as well as the main trunk of the jugular tree should be removed, for we too often find, upon microscopic examination, that a vein or a thrombus, which during the operation appeared to us to have escaped infection, has been invaded by bacteria.

In those cases in which, owing to an inflammatory condition of the vein, the vessel has become soldered to its surrounding tissues, and in consequence is difficult to remove, time should not be sacrificed in trying to exsect it. The main vessel and its branches should be ligated and slit open, and the neck wound should be treated as an open wound.

The attempt to secure primary union in these neck wounds is so contrary to surgical principles and fails so signally that it should not be made. We are scarcely justified in imposing upon an already septic patient, whose fight for life is desperate, the danger of an unnecessary neck infection, when the only advantage gained is a remote possibility of a better cosmetic result.

After the operation is completed it is the custom of some to flush the jugular bulb and that portion of the vein which still remains in the neck, introducing for this purpose the nozzle of a syringe into the vein and forcing the stream through into the sinus, or *vice versa*. If we place carmine granules in the jugular bulb or in the lower portion of the sinus of a cadaver, and practise through-and-through irrigation, the wide dissemination of these granules, to be seen upon dissection, will convince us of the danger of this practice. If through-and-through syringing is done, it is far safer (as can be proved by actual demonstration in the above manner) to irrigate from the sinus through into the jugular —*i.e.*, in the natural direction of the current, than to irrigate from the vein through into the sinus. This is due to the manner in which the tributaries enter the bulb, and also to the arrangement of the plicas about their mouths. Either practice should be condemned.

After the removal of the jugular, a bent curette should be inserted into the bulb end of the sinus, and such portions of the thrombus as can be detached should be removed. During this manipulation, pressure should be made over the upper end of the internal jugular vein of the opposite side, as aspiration of the involved bulb may occur through this avenue.

As the actual resection of the jugular progresses and while the clot is being removed from the lower portion of the sinus, the current of blood issuing from the inferior petrosal, if this vessel be not blocked, fills the bulb, and as the pressure within this cavity rises there is not only a tendency to a slow stagnation within the bulb, but also a tendency to a reversal of the blood currents of the lesser tributaries, along which avenues septic emboli may be swept into the general system. The complete and rapid obliteration of the bulb by a non-infected coagulum is surgically to be desired, for, just in proportion as we can hem in and localize the infected area, do we expect success. If we accomplish this, even though the coagulum in the bulb later becomes infected and broken down through contact with an infected bed, we shall have succeeded in bringing about a sterile thrombosis in the uninvolved tributaries to the bulb and in blocking these avenues of entry to the general system. In order to accomplish this we must eliminate the factors which tend to keep up the currents in the bulb after the jugular has been resected. The most responsible factor for this is a cross current established between the inferior petrosal sinus and the posterior condylar vein, or, in case the latter vessel is absent, through that tributary which is next in size to the inferior petrosal. While the jugular resection constitutes the chief and primary step toward this end, we ultimately accomplish our object (a sudden coagulation) only when we have introduced gauze well into the bulb, or at least as far as the mouth of the posterior condylar.

Shock.—The surgical shock which occurs during or immediately following the operation upon the sinus and jugular is, as a rule, due to loss of blood. If severe, it is best combated by the intravenous transfusion of normal salt solution of proper temperature; if it is slight, the salt solution may be given by enema.

After-treatment.—The after-treatment of the case is similar to that of the mastoid operation. The compression plugs which are inserted between the sinus and skull to control hemorrhage are removed about the fourth day—*i.e.*, at the first dressing; as a rule, no hemorrhage follows, but, should it occur, fresh plugs are inserted and allowed to remain for several days, when they are permanently removed.

Prognosis.—The prognosis in infective sinus thrombosis is always serious. If the condition is detected during the mastoid operation before clot disintegration has occurred, *i.e.*, before the development of pyæmic symptoms, recovery may be expected in the great majority of such cases provided the thrombus is immediately removed. When the symptoms of septic absortion have appeared, the condition must be regarded as grave. Even in this stage, with the thorough removal of the infected clots and the blocking of the avenue of the jugular by resection, the majority of the patients recover. When metastases have developed and the patient has passed into a general septico-pyæmic state, recovery is not the rule; yet even in this class of cases recovery may take place in a small percentage of instances, provided the patient is subjected to thorough treatment by operation.

The general mortality is about twenty-five per cent.

II. PURULENT DISEASE OF THE LABYRINTH.

Etiology.—The important predisposing factors are the acute exanthemata,—particularly scarlet fever and measles,—tuberculosis, and syphilis. In the vast majority of cases purulent disease of the labyrinth results from the extension of a suppurative process from the cavity of the middle ear to that of the labyrinth during the course of chronic purulent middle-ear disease and mastoiditis.

Pathology.—Infection gains access to the labyrinth, as a rule, in one of the following ways:—

1st. Through gradual erosion of the capsule of the labyrinth by a suppurative middle-ear process, in consequence of which fistulæ are formed between the middle ear and labyrinth.

2d. By direct extension of the suppurative process from the middle ear through the round and oval windows, in consequence of which the first cochleal whorl and the vestibule become primarily involved.

3d. By the transmission of infective agents along the avenue of the minute vessels which communicate between the middle ear and the labyrinth. Important in this connection is the plexus of minute veins on the inner tympanic wall, some of which perforate the outer capsule of the labyrinth in the region of the promontory (or that portion which corresponds to the first cochleal whorl) and communicate with similar vessels on the inner wall of the labyrinth.

The pathological changes which take place in the labyrinth when it is invaded by a purulent inflammation vary accordingly as these changes are due to a slow carious process or to an actual suppuration which involves its interior.

(1) Caries most frequently affects the horizontal semicircular canal and the promontory, and the labyrinthine capsule of bone may show at these points simply erosion or loss of surface or cario-necrotic fistulæ. When the labyrinth is opened by a process of erosion, there frequently occurs within the labyrinth, at the site of the destructive lesion, a protective inflammation which seals off the main cavity of the labyrinth from invasion. The affected portion of the capsule disintegrates, and the attempt at spontaneous recovery is observable. In this way a large portion of the labyrinth may still continue to functionate, and it may be seen that, according to the severity of the process, varying degrees of destruction, both as regards function and as regards anatomical structure, may be present. Inasmuch as the carious area may be local and a large portion of the labyrinth may still be uninvaded, its limit frequently represents the limit to which the labyrinth is surgically involved, and, to insure healing, it is necessary to remove only the carious area.

(2) When the labyrinth is invaded by a true suppurative process, its entire cavity, owing to the fact that it represents a continuous channel, is, as a rule, involved. Different portions may show different degrees of destruction, but the whole suffers. As it is through the round and oval windows that the suppurative process usually gains entrance, it is the first cochleal whorl and the vestibule that become primarily involved and show the greatest pathological change. The stapes may be absent, and the oval window may be perforated and filled with granulations which protrude from the vestibule. The cavity of the vestibule and cochlea may contain both granulations and pus. As the purulent process augments, the unyielding labyrinthine capsule suffers profoundly and may become perforated from within outward in order to afford escape to the purulent contents. Through these fistulæ the pus is discharged into the middle-ear cavity, or as sometimes happens, though rarely, it escapes into the cerebellar fossa through a perforation in the inner labyrinthine wall. In these cases in which fistulæ are present and in which partial drainage of the labyrinth has taken place, simple inspection may fail to detect the presence of pus in that cavity; it escapes as rapidly as it is formed. The interior of the labyrinth may merely be filled with granulations of various sizes, some of which may protrude through the fistulous openings as polypoid masses blocking the exit of pus.

(3) The two pathological processes mentioned above may be both present in the same case. The destruction may extend beyond the confines of the labyrinth, involving the entire petrous portion of the temporal bone and causing erosion of the carotid canal. Necrotic areas and sequestra of varying sizes may

occur, and the entire cochlea or portions of this structure may exfoliate. Owing to the fact that its capsule is traversed by planes of cleavage along which separation is more likely to occur, the exfoliation of the labyrinth may be characterized by the casting off of quite large portions of its structure.

The following data gathered from thirteen consecutive cases will illustrate in some measure the relative frequency with which the various portions of the capsule are involved:—In all there were nineteen fistulæ, eight of which perforated the outer wall of the labyrinth, while only one passed through the inner wall. The arch of the horizontal semicircular canal had disappeared in ten; the oval window was perforated in six, the promontory in one, the inner wall of the vestibule in one, and the solid angle of the canal system in one. Many of the cases presented multiple fistulæ.

Symptomatology.—As the labyrinth is the seat not only of the special organ of hearing, but also of that apparatus which influences the co-ordination of the movements of the body, its invasion results in disturbances of the function of both these structures. Lesions of mild intensity produce irritative phenomena, while those of a destructive character cause abolition of function. Between these two extremes are lesions of all degrees, with varying severity in the symptoms produced. An irritative lesion may subsequently become destructive in character, and the symptoms due to irritation, which at first were marked, may subsequently subside and completely disappear. Again, the rapidity with which the labyrinth is invaded influences the severity of the symptoms. With the rapid invasion of that portion of the labyrinth which is concerned in equilibration, there will be pronounced disturbances of inco-ordination—such, for example, as vertigo and nystagmus. If the invasion takes place gradually, as it is likely to do in the course of chronic suppurative or carious processes, these disturbances of inco-ordination may be latent or altogether wanting, owing to the fact that compensation has been established and has kept pace with the destructive process. As a result, therefore, of the disturbance of the special organs within the labyrinth, the following symptoms are to be looked for when that structure is invaded:—

(*a*) *Symptoms Due to Disturbances of the Acoustic Apparatus.*—Tinnitus.—This symptom, when present, is, as a rule, transient. It may be constant or intermittent, and the ringing may be either of high or of low pitch. If careful examination is made of the patient's history, it will generally be found that this symptom has been present at some stage of the disease. In many cases also it will be found that it has not attracted the attention of the patient. It disappears usually after the lesion has become destructive in character, and may be regarded as an irritative phenomenon.

Loss in the Acuity of Hearing.—The deafness observed varies in degree, from slight impairment to hear the spoken voice, to absolute deafness. The watch, the acoumeter, or the tuning-fork, when placed in contact with the skull, may not be heard in the affected ear. If the destructive lesion is limited to the semicircular-canal system or to a portion of it, the disturbance in hearing is not so profound as when the cochlea is involved. The encroachment upon the labyrinth at any point, however, seriously affects the hearing and generally suffices to destroy the perception of conversational tones.

(*b*) *Symptoms Due to Disturbances of the Apparatus of Co-ordination.*—These symptoms are vertigo, vomiting, and nystagmus. They vary in severity according to the rapidity with which the labyrinth is involved. They are usually more marked when the invasion of the labyrinth occurs in the course of an acute than when it occurs in the course of a chronic suppurative middle-ear disease.

Vertigo.—Vertigo may be slight and transient, or it may persist over a period of weeks or months. There may be merely a subjective sensation, on the part of the patient, that his balance has been disturbed, and he recovers himself before his equilibrium has been actually upset. The vertigo is entirely subjective. Again, the vertigo may be of such degree that the patient is unable to walk or to stand alone, and even when he is in the recumbent position all external objects seem to whirl about him and he is unable to appreciate his position relatively to the objects of the external world. As the lesion changes its character from an irritative to a destructive one, the vertigo subsides. It appears that he direction in which the patient tends to fall, when he is standing in the erect posture, varies somewhat with the particular part of the labyrinth involved, although this association has not as yet been satisfactorily worked out. As a rule, the patient tends to fall to the uninvolved side, *i.e.*, away from the labyrinthine lesion. Occasionally he tends to fall backward, more commonly in no definite or constant direction.

When present, vertigo is a most important symptom; it is frequently absent, however, or it is impossible to elicit it by subjecting the patient to the various tests.

Vomiting.—The vomiting is associated with nausea. This symptom rarely occurs except during the period of acute labyrinthine invasion. It is an irritative phenomenon and consequently transitory. The combination of slight vertigo (subjective) and vomiting, accompanied by nausea, with those symptoms which are dependent upon the suppurative process itself (headache, malaise, slight fever, furred tongue, etc.) makes a clinical picture identical with that of a severe "bilious" attack. Unless attention is directed especially to the ear, the condition is likely to pass unrecognized. In obtaining from a patient the history of his chronic suppurative ear disease, the surgeon may elicit the fact that he once had such an attack.

Vomiting is rarely present except in conjunction with vertigo or nystagmus, and it does not possess the same diagnostic importance as does either of these symptoms.

Nystagmus.—This may vary in intensity from a gross rotary motion of the eyes, with reference to no particular axis or plane of motion, to a fine oscillatory motion of the globes, which is only manifest or to be elicited upon directing the eyes in certain meridians. Though nystagmus is an important symptom of labyrinthine invasion, it is one which the patient rarely notices, as the rotary movements of the globes give no subjective sensation that the objects in the field of vision are moving. This symptom presents, as a rule, the following features:— It is most marked when the eyes are turned from the labyrinthine lesion,—*i.e.*, away from the involved ear,—and is most manifest when the eyes are directed to the extreme positions in the horizontal plane. It is least marked, or may be absent, when the eyes are directed downward in the vertical meridian. The primary direction of the oscillatory movement is away from the labyrinthine lesion. While wheel rotation of the globes is occasionally observed, the direction of the oscillatory movement is generally in the horizontal plane.

Other Symptoms of Involvement of the Labyrinth.—In addition to those symptoms which are dependent upon the disturbance of the special organs contained within the labyrinth, there may be other symptoms which are due to inflammatory conditions associated with the suppurative process itself. Such, for example, are headache, malaise, slight fever,—a high temperature with chill is indicative of some complication beyond the confines of the labyrinth,—and paralysis of the seventh nerve. The close relationship between this nerve and the labyrinth, throughout a part of the former's course, affords a ready explanation of the fact that the nerve sometimes becomes involved secondarily in the labyrinthine inflammatory process.

Complications of Labyrinthine Suppuration.—Aside from the destruction or impairment of the organ of hearing and that of equilibration, the complications of purulent disease of the labyrinth are such as to render it one of the gravest conditions incident to suppurative middle-ear and mastoid disease. Owing to the fact that the cavity of the labyrinth is more closely related to the cerebellar fossa (both from position and through communicating avenues) than to the remaining cranial fossæ, the structures in the former fossa are those which are most frequently involved primarily.

The common complications are:—

(1) Extradural abscess on the side toward the cerebellum or a localized collection of pus between the dura and the skull.—This abscess is usually situated on the posterior aspect of the petrous pyramid, in the vicinity of the internal auditory meatus. By working its way outward along the posterior aspect of the petrous bone, the pus may perforate the inner mastoid plate. If the condition remains extradural and if operative measures are instituted before intradural complications have arisen, recovery is the rule.

(2) Purulent lepto-meningitis or the invasion of the endocranial lymph sac, the arachnoid, and the pial membranes by the purulent process.—The purulent invasion tends, as a rule, not to become localized, but to spread rapidly throughout the entire cerebro-spinal axis; and, associated with this inflammation, there is at the same time an encephalitis. Although an occasional operative recovery is reported, the condition may be looked upon as practically fatal. It is one of the frequent complications of labyrinthine suppuration.

(3) Cerebellar abscess or a localized collection of pus within the substance of the cerebellar lobe is frequently dependent upon or associated with a suppuration of the labyrinth.—This condition gives a symptomatology which may be identical with that of suppurative disease of the internal ear, and the one may

therefore easily be mistaken for the other. If not relieved by an operation, the condition is fatal.

(4) Infective thrombosis of the intracranial sinuses.—The sigmoid, the lateral, the superior and the inferior petrosal sinuses, and the jugular bulb may become involved in a purulent phlebitis or thrombosis as the result of extension of the suppurative process from the labyrinth along the avenues which communicate between this cavity and the venous channels in question. As the veins of the semicircular canal system and vestibule empty through the vena aquæductus vestibuli into the lateral sinus, and those of the cochlea empty into the inferior petrosal sinus, the manner in which extension occurs is readily seen.

Septic involvement of the intracranial sinuses is attended by the symptoms of septico-pyæmia—chills, remittent fever, sweats, emaciation, etc. Other and somewhat rare complications of labyrinthine suppuration are ulceration and thrombosis of the carotid artery, general septico-pyæmia, and acute internal hydrocephalus.

Diagnosis.—It may not be possible to make the diagnosis of labyrinthine suppuration upon symptoms alone, as these may be absent or latent, but the condition is to be suspected when the following symptoms make their appearance in the course of either acute or chronic suppurative ear disease: vertigo or nystagmus, associated with marked impairment of the hearing. We will now consider these more in detail.

Vertigo or nystagmus may or may not be associated with vomiting. When the tuning-fork test is applied it is found that both air and bone conduction are less than normal; that the sound of the vibrating fork is apparently heard better in the unaffected ear (if normal), and that the range of audition is diminished, both the upper and the lower limits of the scale being affected. Frequently, however, the sound of the tuning-fork is heard better in the involved ear, and bone conduction is not shortened in duration on the affected side. Unfortunately, the tuning-fork, as an aid in diagnosing middle-ear from labyrinthine lesions, is not as important as is generally supposed, and it may be added that these labyrinthine cases respond in no constant manner to tuning-fork tests.

As the vertigo and nystagmus may be latent, we may resort to several tests in order to elicit these symptoms or to determine if they are present to an abnormal degree. To ascertain whether the patient is or is not able to maintain his balance, he is made to stand with eyes closed, first on both feet, then on each foot separately. Under these conditions there may be an abnormal tendency to fall; usually this is either to the side of the labyrinthine lesion or to the opposite side (the direction is not constant), and occasionally the patient tends to fall backward. When he attempts to walk in a straight line, either with closed or with open eyes, he may manifest a decided tendency to deviate to either side.

In the next test the patient is made to hop forward, first with eyes open, then with eyes closed, and, at the conclusion of the hopping, it is necessary to note how far he is able to maintain his balance.

As to the nystagmus, one may proceed in the following manner:—The patient should be placed in a revolving chair and, after he has been rotated in the horizontal plane through a dozen revolutions, the movement should be suddenly arrested and the patient directed to fix the open eyes in extreme deviation, first to the right, then to the left. If he has latent nystagmus, he will now manifest the symptom in an unmistakable manner. Again, if the ear of a patient, whose labyrinth is in a condition of abnormal irritability, be syringed with a continuous stream of cold water, the symptom of nystagmus may manifest itself to an exceptional degree.

It often happens, however, that the diagnosis of labyrinthine suppuration is not made until operation upon the mastoid and middle-ear cavities reveals the fact that cario-necrotic fistulæ pass through the capsule of the labyrinth, or that pus is issuing through the inner tympanic wall. A large proportion of these cases give no symptoms whatever that point definitely to the internal ear as the seat of trouble, and are—so to speak—discovered accidentally at the time of operation. Further, it is not always possible, even after the complete exposure of the inner tympanic wall by operative procedure, to decide whether the labyrinth is invaded or not; for such symptoms as vertigo, vomiting, nystagmus, and inco-ordination may result from labyrinthine disturbance caused by transmitted pressure from the middle-ear cavity, by polypi, by cholesteatomata, by pus under pressure, etc. In addition, the defective hearing may be accounted for by the middle-ear lesion. In such cases, where labyrinthine symptoms have been present and where operation reveals no fistulous opening through the capsule of the labyrinth, the writer has found the following test to be of value:—Intermittent pressure upon the capitulum of the stapes, effected by means of a probe, will in some instances induce nystagmus; and, when this happens, the inference is warranted that the labyrinth is functionating and therefore is not grossly involved in a destructive lesion. The condition with which suppurative disease of the labyrinth is most likely to be confounded is cerebellar abscess, originating from suppurative ear disease. The following points may serve to distinguish the one from the other, although the differential diagnosis is often difficult or impossible. In cerebellar abscess (in addition to vertigo, nystagmus, and the disturbances of co-ordination which are not to be distinguished from those of labyrinthine origin) the following signs or symptoms may be present:—choked disc or optic neuritis of one or both eyes; vomiting of a projectile character; intense headache which frequently is referred to the fronto-parietal region of the involved side; paralysis of the abducens; subnormal temperature; inequality of the pupils, frequently associated with dilatation of the pupil of the corresponding side; slowing of the pulse; a change in the character and rapidity of the respiratory movement; a decrease in the superficial and deep reflexes; the presence of areas of anæsthesia or hemi-anæsthesia of the affected side; and marked disturbances of cerebration, such as hebetude, irritability, etc. Again, the hearing may not necessarily be profoundly disturbed.

Indications for Entering the Labyrinth.—(1) If, during operation upon the middle-ear and mastoid cavities, fistulæ are detected in the labyrinthine capsule, or if it is seen that the interior of the labyrinth is involved, this part of the ear must be explored, even though there be no symptoms.

(2) If, prior to operation, the symptoms are such as to lead to the diagnosis of labyrinthine disease, and yet if, upon operating, it be found that the outer labyrinthine wall shows no fistulæ and that no other evidences of invasion of the labyrinth are discoverable, it is safer not to explore this cavity; for the symptoms which appeared to point to labyrinthine involvement frequently subside after the middle-ear and mastoid cavities have been cleaned. If, however, accompanying the labyrinthine symptoms, there is evidence of meningeal irritation, or if high fever is present and the symptoms seem grave, the labyrinth must be explored at the primary operation even though to outward appearance it is normal. For it must be remembered that the interior of the labyrinth may be involved in a suppurative process (the extension having taken place from the middle ear through the communicating vessels), notwithstanding the fact that the outer capsule of the labyrinth is normal in appearance.

(3) If, subsequently to operation for suppurative middle-ear and mastoid disease (particularly that of the chronic type) labyrinthine symptoms appear and are accompanied by high fever, restlessness, or symptoms of meningeal irritation, the labyrinth should be immediately explored; for operation upon the middle-ear and mastoid cavities may light up and make active a smouldering labyrinthine process that will then be likely to spread rapidly to intracranial structures.

Subsequently to the radical operation for chronic suppurative middle-ear disease a slight nystagmus and some vertigo are occasionally observed; but both of these symptoms may be of a transient character, being due to the dislocation of the stapes or to pressure upon this ossicle by the packing. Under these conditions the symptoms are slight and soon subside, and are not likely to be mistaken for the graver labyrinthine involvement just referred to. This accident, however, is a serious one.

Treatment.—The treatment of labyrinthine suppuration is essentially surgical. When the labyrinth is involved in a carious process the limit of the carious area frequently represents the surgical limit of the disease, and it is necessary to remove only this carious area, without attempting a complete exenteration of the labyrinth. When, however, the labyrinth is invaded by a true suppurative process, the involved area embraces, as a rule, the vestibule, the cochlea, and the canal system, either in whole or in part; and, in addition, the bony capsule of the labyrinth is itself profoundly diseased. Under these conditions a complete or a partial exenteration of the labyrinth is necessary. As a description of the complete exenteration of the labyrinth will embrace all the steps requisite for the removal or exposure of any individual portion of the organ, that procedure alone will here be considered.

Complete Exenteration of the Labyrinth.—The steps required in this operation are the following:—First, the mastoid and tympanic structures should be completely removed, as is done in a Schwartze-Stacke operation. (See page 715 et seq.) In this way we shall secure the maximum amount of working room, and shall also be able readily to exenterate the bony angle included between the groove of the sinus knee and the under surface of the middle fossa, the removal of which parts makes it easier to work in the axis of the petrous pyramid. We lower the ridge for the facial nerve to its absolute limit and then remove the fringe of bone on the anterior aspect of this ridge back to the descending limb of the facial nerve; we also remove the outer wall of the hypotympanum, and lower the level of the floor of the external auditory canal, securing by these steps the maximum

FIG. 376.—In this illustration are shown the results of an incomplete Schwartze-Stacke operation. Anteriorly a lip of bone overhangs the tympanic orifice of the Eustachian tube. The Fallopian canal containing the facial nerve is visible just above the promontory. The arch of the posterior semicircular canal is delineated in the lower part of the picture. (Original.)

exposure of the outer wall of the vestibule and also of the dome of the jugular bulb should it rise to a greater height than usual.

As exploration of the cochlea may be necessary, it is important that we see the exact position of the carotid artery by the exposure of its canal. To attain this object we shave down the convexity of the anterior wall of the auditory canal, remove the lip of bone overhanging the mouth of the Eustachian tube, and evulse the tensor tympani. This fully exposes the tube to view, enabling us thoroughly to curette it, which diminishes bleeding from the mouth of the tube and also gives the maximum width to the apex of the cavity. Should the consistency of the bone permit, the arches of the semicircular canals should be delineated. This enables us to work with accuracy. (Fig. 377.) The cavity should be cleansed, the tube packed with adrenalin gauze, and the field rendered bloodless. The instruments and the hands should be resterilized.

FIG. 377.—This illustration shows the Schwartze-Stacke operation completed and the cavity prepared for the exploration of the labyrinth. The arches of the three semicircular canals are delineated. Immediately anterior to these is the facial ridge containing the facial nerve.—Just in front of the facial ridge the two windows leading into the labyrinth are seen. Between these two windows is the posterior aspect of the promontory, in front of which is seen the opening of the Eustachian tube, with the lip of bone which overhangs it removed.—Adjacent to the tympanic orifice of the tube is seen the slight prominence of the carotid canal. (Original.)

Our next step is to remove the prominence of the horizontal semicircular canal—a treacherous structure to deal with. The cutting edge of the chisel is placed at a point below the summit, but well above the level of the Fallopian canal, for this prominence separates along definite planes of cleavage; and, as the outer lip of this semicircular canal is in close relation with the Fallopian canal, a fissure in the former may readily extend out into the latter. Should the plane of cleavage be on a level with or below the Fallopian canal the facial nerve may either be exposed, by having its roof removed (as shown in Fig. 385) or else completely undermined. (Fig. 380.) Under the latter circumstances we may definitely expect paralysis, for it will follow. The stroke of the chisel should be made in a direction corresponding to the plane of

Fig. 378.—In this figure are shown the arches of the three semicircular canals uncapped, with a probe passing through the superior canal into the vestibule and emerging from the oval window. (Original.)

the canal. The remaining canals are next uncapped, and the condition of their interior is noted. It will be found that the interior of the external semicircular canal most frequently of all shows pathological changes. In opening the superior canal a curved gouge should be used. It permits the effects of the stroke to be made in the direction of safety. The danger arises from the non-support of this canal by solid bony structure.

Owing to the contrast between the dark interior of the canals and the brilliantly illuminated white bone surrounding them, the labyrinthine fluid may appear dark and be mistaken for blood or granulations. We should not be deceived by this illusion.

We next enter the vestibule through the solid angle of the semicircular canals by creating at this point a conical pit with its apex directed inward and gradually lowered until it enters the vestibule. As it is necessary to remove

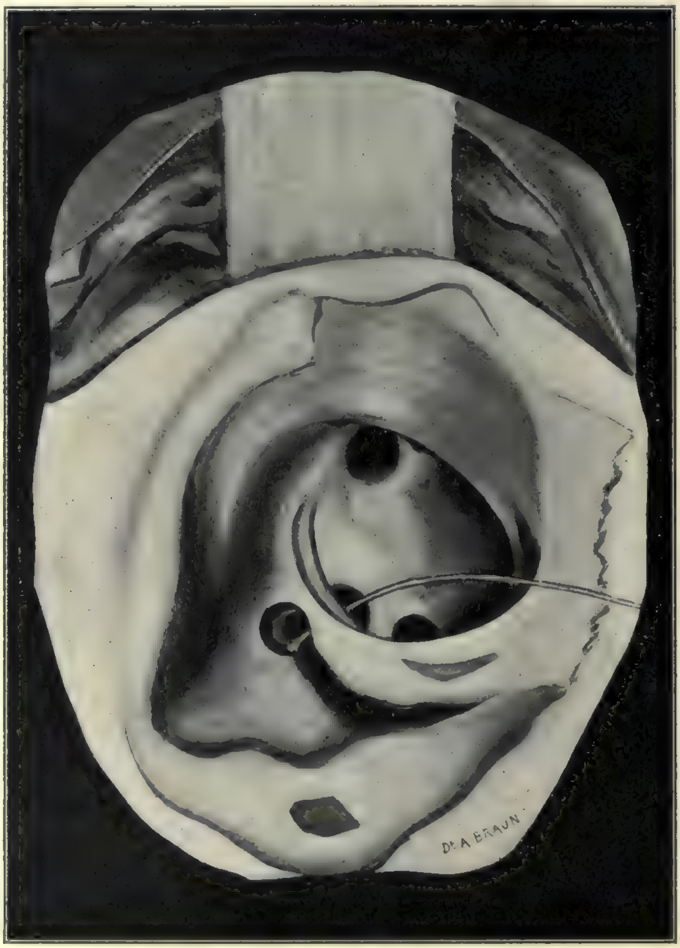

FIG. 379.—This picture shows the arches of the semicircular canals removed and the posterior portion of the vestibule opened. The probe passes through the oval window. Immediately above the probe is seen the Fallopian canal, with such portion of the facial ridge as remains after the removal of the canal arches. In the lower portion of the facial ridge the facial nerve is seen exposed for a short distance. The dura of the sigmoid sinus is shown exposed in the lower part of the picture. (Original.)

the inner lip of the horizontal semicircular canal, the chisel, during this step, should be held perpendicular to the plane of cleavage, and under no circumstances should it impinge upon the outer lip, which is intimately associated with the Fallopian canal. The latter structure, together with the outer lip just mentioned, is left as a bridge, which, carrying the facial nerve, spans the vestibule. (Fig. 379.)

The opening in the vestibule is now enlarged until a full exposure is obtained of this portion of the labyrinthine cavity. Its inner wall should be searched for fistulæ. In enlarging this cavity the surgeon should be careful not to make pressure upon the bridge described above. For this reason a curette is a dangerous instrument; a small gouge is safer.

In some instances, owing to widespread necrosis, it is necessary to sacrifice

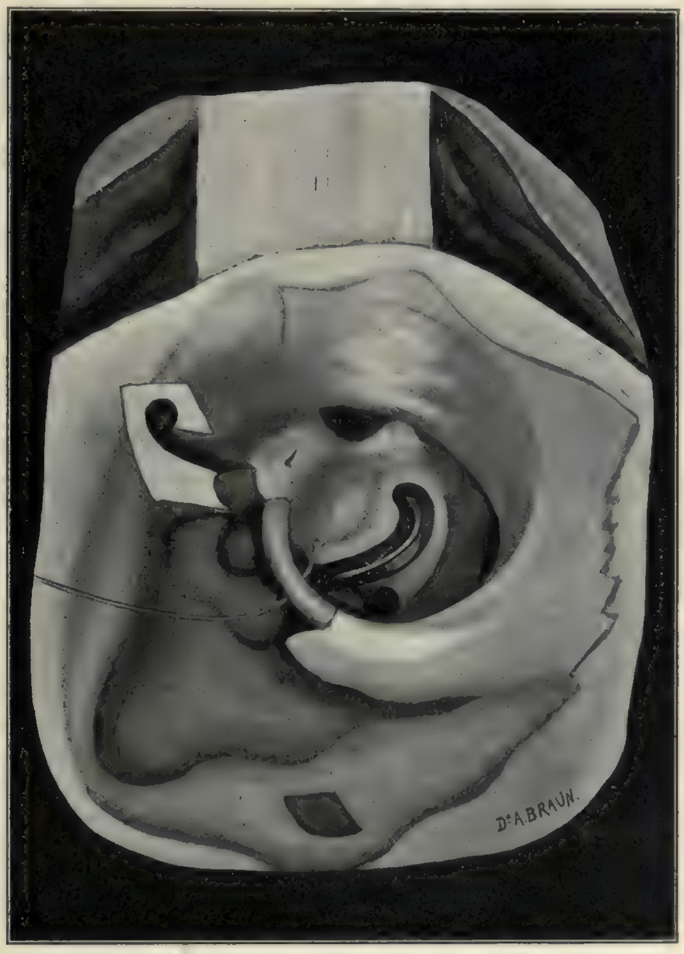

Fig. 380.—The drawing shows the Fallopian canal fractured and the facial nerve exposed and stretching over the cavity of the vestibule. The first half turn of the cochlea is also exposed by the removal of a portion of the promontory. In the depth of the first half turn of the cochlea is seen the white line representing the beginning of the spiral membrane as it winds round the modiolus. (Original.)

the bridge of bone that carries the facial nerve. To accomplish this without injury to the facial, we select a curette with its cutting edge turned backward, utilize the superior rim of the bone cavity as a fulcrum, and shave off (from above downward, in a direction parallel to the course of the nerve) the roof of the Fallopian canal, thus leaving the nerve exposed in its gutter of bone, from which it may be separated and lifted without injury. (Fig. 381.) Any filaments given off from the nerve should be cut and not torn from this structure, as unnecessary traumatism is to be avoided. We next remove such portions of the bridge as are necrotic, but no more, for the nerve here represents an arch-like curve, and, should it lose the entire support of its bony gutter, it apparently elongates and consequently sags or kinks. In this vicious position it is likely

FIG. 381.—This picture represents the roof of the Fallopian canal removed and the facial nerve lifted up from its bony gutter. The dome of the jugular bulb encroaches upon the floor of the tympanum. The posterior portion of the cavity of the vestibule is shown as it appears after the removal of the arches of the semicircular canals. The dura of the midcranial fossa is seen just above the cavity of the vestibule, and the dura of the sigmoid sinus just below it. (Original.)

to become enmeshed by the granulations and subsequently to have its functions interfered with.

Robbed of its support, the nerve stretches as an exposed structure from its point of emergence, low down on the facial ridge, across the cavity of the vestibule, to its entrance into the inner wall of the tympanum, at a point situated above and anterior to the original site of the oval window. (Fig. 380.)

In knocking out the inner edge of the bony bridge, which corresponds to the upper inner wall of the tympanum, one should be careful not to direct the stroke of the chisel from behind forward in a direction parallel to the course of the nerve, but from above downward, or from before backward, *i.e.*, in a direction perpendicular to the course of the nerve and to the Fallopian canal. The reason for this is that the bone at this point tends to separate, when struck from

FIG. 382.—This figure shows the facial ridge preserved after the arches of the semicircular canals have been removed and the vestibule opened. The posterior aspect of the promontory is fractured in a forward direction, revealing the beginning of the first cochleal whorl. The relations of the Eustachian tube to the carotid canal are shown anteriorly. (Original.)

behind forward, along a plane of cleavage which crosses the Fallopian canal, causing its fracture. As the Fallopian canal at this point represents the greater portion of an exposed cylinder (Fig. 376), its fracture results in the facial nerve being encompassed by a little annulus or cylinder of bone, which may be slid up and down upon the nerve, just as a ring slides upon a finger. This complication is—so far as the integrity of the nerve is concerned—a formidable one, and it requires the greatest patience to remove the little annulus without causing injury to the facial nerve. To accomplish it we steady the annulus with mouse-tooth thumb forceps and then, with a rongeur the jaws of which are accurately apposed, crush it in a direction parallel to the course of the nerve. To avoid this complication, it is only necessary, before the removal of the upper portion of the bony ridge is attempted, that the Fallopian canal should have been thoroughly converted into a gutter, by shaving off its roof, as already

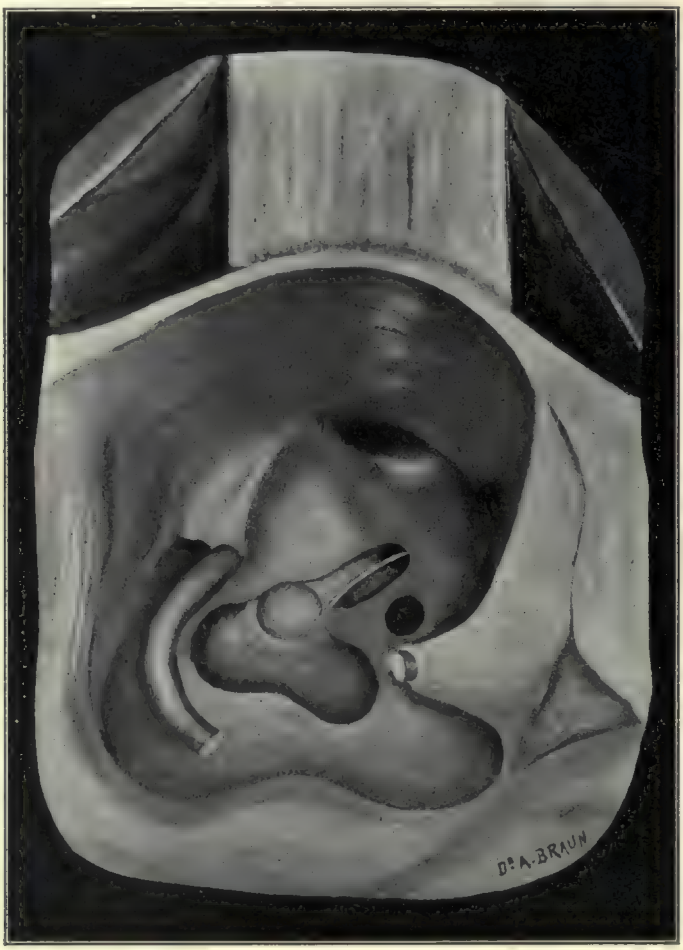

FIG. 383.—The facial nerve, in the picture, has been divided and retracted, and the outer vestibule wall removed so as to expose the inner vestibular wall, upon which is seen the round depression of the recessus sphericus. The roof over the beginning of the first cochleal whorl has been removed, thus exposing to view the spiral membrane. The carotid canal adjacent to the orifice of the Eustachian tube is seen. The round window is seen just in front of the lower end of the facial nerve. (Original.)

described, and by making the stroke of the chisel in the direction indicated. Should the accident now occur, the nerve can be easily freed from the little mass of bone by slipping it through the open side of the annulus or cylinder.

Should it become necessary to expose the nerve in the manner mentioned above and shown in Fig. 380), no attempt should be made to retract it or to draw it to one side for the sake of gaining room for manipulation, as this is unnecessary; for the Fallopian canal, at the points where the nerve emerges from and enters the bone, is represented by sharp, serrated margins, against which—as they are fixed points—the nerve, if drawn across them, may be lacerated. The sharp spicules should be removed so that the margins of the canal at these respective points shall be represented by an even rim.

Fig. 384.—In the drawing the apex of the modiolus is seen through an opening made in the cochleal shell. Minute blood-vessels may be seen coursing over the pyramid of the modiolus, the base of which forms the inner wall of that portion of the cochleal whorl which is exposed to view. The facial nerve is divided at a point corresponding to the lower portion of the facial ridge and retracted so as to expose the inner wall of the vestibule, upon which is seen the round depression of the recessus sphericus. At the point the spiral membrane begins. (Original.)

The next step is to expose the antero-inferior cavity of the vestibule by removing the posterior aspect of the promontory and the outer vestibular wall. (Fig. 382.) For the accomplishment of this, a gouge should be selected the width of which corresponds to the distance between the round and oval windows. The cutting edge of the instrument straddles the little bridge of bone which separates these two openings, and the stroke—only a gentle one, for the posterior aspect of the promontory is brittle and fractures easily—is directed from above downward and forward in the direction of the first cochleal turn. At this step the operator must keep in mind the possible position of the dome of the jugular bulb. He must also exercise the greatest care to prevent the cutting edge of the chisel from crossing the cavity of the vestibule and imping-

Fig. 385.—The drawing shows how the cochleal shell should be opened so as to expose to view the upper portion of the modiolus. The external semicircular canal is fractured in order to expose the facial nerve in its canal. The superior and posterior semicircular canals are uncapped and their interiors are exposed. The round and oval windows are seen anteriorly to the facial ridge. Just in front of the oval window a portion of the promontory has been removed so as to expose the interior of the first cochleal whorl, at the bottom of which the spiral membrane is seen. Just above is seen the artificial round opening in the upper anterior part of the cochleal shell. (Original.)

ing upon its inner wall, for at this point the inner wall bulges outward and is separated from the internal auditory meatus by a partition of bone which is quite brittle and extremely thin (it does not measure more than $\frac{1}{32}$ inch in thickness). (Fig. 391.) Should the inner vestibular wall be fractured, a loss of cerebro-spinal fluid will take place—an accident which not only causes inconvenience but also places the infected operative cavity in direct communication with the intracranial cavity and so jeopardizes the patient's life. In all probability meningitis will result.

As the cerebro-spinal fluid is under pressure and is of low specific gravity, the rent cannot be efficiently plugged with gauze; sterile wax is preferable for this purpose.

By enlarging the opening which he has secured by the various steps described above, the operator will expose fully to view the vestibular cavity and the begin-

Fig. 386.—A section of the cochlea from base to apex of the modiolus, showing the base of the pyramid excavated by the internal auditory meatus which renders the pyramid liable to fracture at its base when the attempt is made to remove the pyramid in its entirety. Different levels of the cochleal spiral are revealed as it winds around the pyramid. (After Politzer.)

ning of the first cochleal whorl. If he should now find that the disease has invaded the cochlea,—and this is the rule in the second class of cases,—he must continue the exploration of the cochlea until he shall have followed the diseased process to its legitimate end.

The roof of the first cochleal whorl should next be removed from behind forward, thus exposing its interior to a point just short of the carotid eminence. (Fig. 038.) The instrument best adapted to this work is a thin, sharp gouge which has no shoulder and the width of which is slightly greater than that of the cochleal whorl. Four structures are to avoided: the dome of the jugular bulb below, the eminence of the carotid canal in front, the base of the modiolus, and the internal auditory meatus. So far as the first two are concerned, the danger

FIG. 387.—The outer cochleal shell has here been removed in such a manner as to expose the modiolus, the apex of which has been removed down to a point corresponding to the termination of the first cochleal whorl. The probe winds round the modiolus, and, immediately above the concealed portion of the probe, is seen the roof of the second half of the first cochleal turn, which may be removed from above downward by working over the stump of the pyramid. (Original.)

is slight; whereas, in the case of the last two, it is imminent. Injury to these structures, it should be remembered, is to be avoided only with the exercise of care. It is necessary, for example, if one wishes to avoid these dangers, to remove only so much of the cochleal shell as represents the roof of its first whorl, and not to allow the gouge to impinge upon the inner wall of the cochleal turn. From the carotid artery in front, the cavity of the first cochleal turn is separated by a hard cuff of bone which serves the purpose of an efficient bumper. Although it is thin, this partition is sufficient. (Fig. 387.)

If it is now found that the limit of the disease has not been reached, it will be necessary to explore the remaining cochlea. This constitutes by far the most difficult and dangerous step of the procedure; for the cochlea, which represents an extremely small cavity encased in a brittle shell of bone, is hemmed in on all

FIG. 388.—This illustration shows the roof of the second half of the first cochleal whorl removed in such a manner as to expose the deep anterior portion of the cochleal cavity. (Original.)

sides by structures which it is not permissible to injure. In front is the carotid artery; below is located the dome of the jugular bulb; behind lies the internal auditory meatus; while above and behind, in immediate proximity to the second half of the first cochleal turn, is placed the knee of the facial nerve. A circle a quarter of an inch in diameter could be so placed as to pass through the majority of these structures.

Were the above factors the only ones to be considered, it would be comparatively easy to select, on the cochleal shell, a point from which an entrance might safely be made into the cochleal cavity. But the difficulty lies in the fact that within this shell of bone is contained a structure—the modiolus—which, from its position, is particularly exposed to injury, and which, from a surgical standpoint, is the most treacherous part of the internal ear.

Before one attempts to effect an entrance into the cochlea he would do well to consider certain anatomical features of the modiolus. This structure repre-

Fig. 389.—In this picture the pyramid is represented as fractured at the base. The internal auditory meatus is opened and the cochleal branch of the auditory nerve may be seen. (Original.)

sents a small pyramid of bone which is seated upon the internal auditory meatus. Its apex is its weakest point, but the next weakest point is not immediately below its apex, but at the extreme base; for its base is excavated, as shown in Fig. 386 (Politzer), by the internal auditory meatus; and the pyramid consequently rests upon a mere rim of thin, brittle bone. If the chisel is applied to the pyramid well above its base, and a stroke is made, the fracture does not take place at the point of applied violence, but at the base; and when this occurs the pyramid fractures completely round the circumference of its base and separates as a single piece of bone. (Fig. 389.) The internal auditory meatus is consequently opened throughout its entire circumference, and, as the diameter of the base of the pyramid (or the rim of bone upon which it rests) measures about one-sixth of an inch, the loss of cerebro-spinal fluid takes place rapidly.

If we next examine the modiolus with a strong convex lens we see that the pyramid has an outer casing of brittle bone and a core which is porous; this

Fig. 390.—This illustration shows the appearance of the interior of the cochleal cavity after the complete removal of the modiolus following a fracture at its base. The cochleal branch of the auditory nerve is seen in the internal auditory meatus. The picture also shows the knee of the facial nerve and its relation to the lower cochleal whorl. (Original.)

porousness being due to the fact that canals containing various soft structures pass through it from base to apex. These canals are not completely filled by the structures which they contain, and hence it is possible for the cerebro-spinal fluid to penetrate out into the modiolus.

If in his further advance the operator should remove the modiolus well down toward its base, seepage of cerebro-spinal fluid may take place through its stump, and the intracranial cavity may be placed in free communication with the infected cavity through the afore-mentioned channels. It is therefore important to determine how far down from the apex, toward the base, the pyramid may be removed without putting the intracranial and operative cavities in free communication; for, in dealing with the anterior half of the cochlear cavity, it is absolutely necessary to get rid of a portion of the modiolus.

If, in a cadaver, we increase the tension of the intracranial fluid by means of an injection, or if, in the living subject, we exert pressure over the internal jugular vein and thus cause the cerebro-spinal fluid to penetrate as far out as possible into the modiolus (*i.e.*, grossly), it will be found that the pyramid may be removed, in the direction from the apex toward its base, down to a point corresponding to the termination of the first cochleal whorl, without causing the loss of cerebro-spinal fluid—*i.e.*, without placing the operative and intracranial cavities in gross communication. As will be shown later, this suffices for the complete exploration of the anterior half of the cochleal cavity.

In approaching the cochlea, therefore, the operator should remove its shell in such a way as not to injure the modiolus. He should select, in the cochleal shell, a point that corresponds as nearly as possible to the apex of the cochleal cavity, and with a thin, sharp instrument he should shave it down until the dark interior of a cochleal whorl shows through the thin lamella of bone. The stroke of the chisel should be made from above downward and forward in a direction corresponding to that of a cochleal whorl. (It should be remembered that in not a few instances the shell of the cochlea is scalloped and that the position of each cochleal turn is roughly indicated.) Advancing in this way the operator establishes a window in the cochleal shell (Fig. 385), and then he enlarges this window to such a degree as completely to expose the upper portion of the cavity. (Fig. 384.) For the enlargement of this window the small gouge is the instrument of preference; for an attempt to insinuate a very fine curette beneath the opening in the cochleal shell causes the back of the instrument to impinge or press upon the modiolus, which sticks up as a little tent-pole in the cavity, and this may result in the fracture of the pyramid at its base. The gouge merely removes the shell without endangering the pyramid.

To expose the second half of the cochleal whorl it is necessary to remove the apex of the pyramid down to a point corresponding to the termination of the first cochleal whorl, as shown in Fig. 387. This done, one may look down, over the stump of the pyramid, upon the roof of the second half of the first whorl (which is indicated by the probe in Fig. 387). Then, to break through this roof, it is necessary to employ a small gouge, which is made to advance very cautiously from above. In this way the entire interior of the cavity of the cochlea may be brought into view, as shown in Fig. 388. In breaking through the roof over the last portion of the first whorl, the operator must bear in mind that his chisel is in close proximity to the facial nerve and the internal auditory meatus, both of which parts should be avoided.

In Fig. 387 the probe is wound round the base of the modiolus merely for the sake of illustrating the relations of the roof of the second half of the first whorl. An attempt to withdraw the instrument might easily cause the modiolus to fracture. Such a step would not be taken during an actual operation.

In removing the petrous portion of the temporal bone the operator will find that it is best to exenterate it and later to remove its shell. Unless this course is followed, the dura of the posterior and middle fossæ bulges into the

FIG. 391.—In this illustration are shown the surgical relations of the cochlea and vestibule as seen from above. A brittle partition of bone, about $\frac{1}{32}$ in. in thickness, separates the internal auditory meatus from the cavity of the vestibule. The cochlea is seen to rest directly upon the internal auditory meatus. Just anterior to the cochlea and separated from it by a thin partition is the carotid artery. External to the artery is seen the tensor tympani muscle lying just above the Eustachian tube. The foot-plate of the stapes is shown in position. The two round openings are sections of the semicircular canals. On the floor of the vestibule is seen the orifice of a semicircular canal. The attachment of the tendon of the tensor tympani to the malleus and also the stapedius muscle are shown in the picture. (Original.)

wound, narrows the field of operation, which is extremely deep, and prevents a satisfactory view of the parts. If this bulging of the dura occurs it will be necessary to retract it, but the best retractor is the shell of the petrous pyramid, which inflicts no trauma, occupies no space, and is accurately applied to the surfaces to be supported.

A second reason for first removing the interior of the petrous bone and allowing the shell to remain until the last, is that the dura which encloses the superior petrosal sinus is firmly attached to the upper margin of the posterior aspect of the pyramid and can be separated from this uneven lip only with difficulty. In consequence, the vessel may easily be torn, which would of course be followed by a sharp hemorrhage that is difficult to control, for it is not easy to place a compression plug between the dura and the bone, as the two do not readily separate. If the accident in question is to occur it is more convenient that it should occur toward the end of the operation.

The operator should endeavor to save the facial nerve by preserving a bridge of bone from the lower portion of the facial ridge to the internal auditory meatus. For the accomplishment of this he will require much patience. But even though the nerve be sacrificed, he should still attempt to preserve the bridge, as it serves the further purpose of giving the dura of the middle fossa a seat upon which it may rest and thus escape sinking deeply into the wound and becoming sealed in this position to the bed of granulations that spring from the floor.

When the dura is not supported, it sags into the excavation and shuts off the apex of the field of operation, thus rendering this part difficult to attack. It also later obstructs drainage. No amount of pressure secured by packing with gauze suffices to maintain the dura in a proper position, as the gauze soon becomes soaked and its power to support the membrane is then lost. Should it become necessary, for any reason, to reoperate upon a case of this character (and this contingency may arise, owing to the fact that portions of necrotic bone may at the primary operation be overlooked and subsequently give trouble) it will be found that the dura, sealed in its vicious position, is a hindrance to further surgical interference. Again, various dyscrasiæ may also underlie such extensive destruction as is here cited and, by causing death of bone subsequently to the primary operation, force us to reoperate. For this reason the operation should be done thoroughly and all dead bone in the deep, apical portion of the pyramid should be removed. When the bridge is sacrificed the nerve, which represents a curve, is exposed over a considerable portion of its length, and it then kinks and becomes enmeshed later in the bed of granulations. These conditions naturally interfere with the function of the nerve.

It is dangerous to attempt to remove sclerosed portions of the pyramid with the rongeur. The force requisite for a bite of the forceps is great, the bone suddenly gives, and, as the jaws of the rongeur spring together, sharp slivers of bone are thrown with violence against the tightly stretched dura of the cerebellum and may easily perforate it. In this way an opening may be established in the posterior fossa.

It is important that the operator should be familiar not only with the surgical anatomy in the operative position, but also with the consistency of the different parts of the petrous bone and with the result that may be expected from a stroke of the chisel when made in a definite direction; for the bone of the petrous pyramid is structurally treacherous, changing rapidly from pneumatic to sclerosed structure, which latter, when struck, may crack far beyond the point of applied violence and in a direction contrary to that expected. We can obtain a practical familiarity with this important part of the technique only by repeated work upon the cadaver. (To attempt a description of this part of the technique is useless.) Generally speaking, we should, when attempting to remove sclerosed portions of the labyrinth, make the stroke in the long axis of the cavity which the sclerosed bone covers. While this statement is not invariably true, it comprises as much of the truth as any general statement can be made to contain.

In operations upon the labyrinth the condition of the carotid artery sometimes demands attention. When the bony canal surrounding this artery is extensively eroded and the vessel itself is exposed to view, pulsation, as a rule, is not visible. If pressure is made upon the artery with an applicator wound with cotton and the lumen of the vessel is momentarily constricted, slight pulsation may be elicited. It is a fortunate provision that the vessel does not forcibly pulsate at this point and impinge upon the sharp serrated margin of the eroded canal, for the walls of the contained artery, being exceedingly thin through the lack of any necessity for their full development, might be lacerated. The carotid canal serves a twofold purpose: First, it acts as a bumper to the pulse wave, receiving its impact and shielding the brain from excessive shock; and, second, as the canal is rigid and does not permit the artery to dilate except within narrow limits, it has the practical effect of constricting that portion of the artery within its grasp. The effect is the same as when with the fingers we constrict the lumen of a rubber tube through which water is being forced by a rubber bulb; *i.e.*, there is a tendency under these conditions for the intermittent or remittent current to approximate a continuous stream. The carotid canal, therefore, not only protects the brain from excess of pulse impact, but acts at the same time as a mechanism by which the inflow of blood to the brain is somewhat regulated and made more even and continuous. It is analogous to the hydraulic arrangement of the jugular bulb and sigmoid sinus on the venous side of the circulation, whereby an even outflow of blood from the brain is guaranteed.

Prognosis.—As to Hearing.—When the labyrinth is invaded by suppurative disease or encroached upon by operative procedure, the organ is, as a rule, rendered valueless for practical purposes of hearing.

As to Life.—The mortality following the operation for purulent inflammation of the labyrinth is about twenty per cent.

After-treatment.—The dressing of the wound in these cases is similar to that following the radical operation for chronic suppurative otitis media.

Sequelæ.—Immediately following an operation upon the labyrinth or subsequently the following phenomena may appear:—

If the operation has encroached to any extent upon a labyrinth that is still capable of performing its functions, particularly in cases where both the canal system and the vestibule are removed, there will follow, in the great majority of instances, disturbed equilibrium, nystagmus, and vomiting (accompanied by nausea). The vertigo is more pronounced when the patient makes an attempt to assume the sitting posture; and closure of the eyes augments the disturbed equilibrium. As a rule, the tendency is to fall toward the side opposite to that of the labyrinthine lesion. At first, the nystagmus may be of marked rotary character—the globes rotate beneath the closed lids, and nystagmus is independent of an attempt to fix the eyes upon an object. Nystagmus may be present in any direction which the eyes assume. In a few days a marked decrease occurs, and, as a rule, though not always, the greatest excursion of the globes is in the horizontal plane. At first, the oscillatory movements may be very feebly marked; later, they are more pronounced, sluggish, and jerky. The apparent delicateness or coarseness of the movement appears to be dependent upon the rapidity of oscillation.

The nystagmus, as a rule, presents the following features:—

(1) It is most marked when the patient looks either to the extreme right or to the extreme left lateral position.

(2) When the eyes are directed to the upper vertical meridian, slight nystagmus may be observed. At first, this may appear vertical in direction, but upon careful inspection a slight rotary movement will be seen. This latter is possibly due to the action of the extrinsic muscles of the eye.

(3) When the eyes are directed to the lower vertical meridian, the nystagmus is slightest, or even—and this is the rule—absent, although it may be present in other meridians.

(4) The nystagmus is most marked when the eyes are directed to the extreme lateral position of the normal side. Even after the nystagmus has totally disappeared in all other meridians, it may still be made manifest when the eyes are turned in the direction opposite to that of the labyrinthine lesion. Occasionally the patient tends to fall to the side of the labyrinthine lesion, and not to the opposite side. When this occurs, the nystagmus may be most marked when the eyes are directed to the extreme lateral position of the operated side, or equally as marked as when turned to the normal side. There appears to be some harmony in respect of the direction in which disturbed equilibrium and nystagmus are most manifest.

The vertigo and the vomiting which follow an operation upon the labyrinth cease, as a rule, in a few days, and disturbed equilibrium and nystagmus soon subside. The patient, however, when attempting to walk a straight line, may show for some weeks or months subsequently to the operation a tendency to deviate from the involved side; he may tend to fall in this direction immediately after the operation. In other cases all disturbances of equilibrium disappear in a few days. This tendency to fall or to deviate from the side of the labyrinthine lesion occurs in cases in which the horizontal canal alone is removed, in those in which the canal system and vestibule are both removed, or in those in which the entire labyrinth is removed. In some cases a slight nystagmus may be observed for months after the operation; it may persist for years.

In some instances where the nystagmus is not of sufficient degree to be manifest when the eyes are directed to infinity, it may be made so by having the patient suddenly converge and accommodate, although this is not the rule.

The primary direction of the oscillatory movements is away from the labyrinthine lesion; *i.e.*, if the left labyrinth is involved, the direction of oscillation is from left to right, or *vice versa,* no matter in what direction the eyes are turned.

The nystagmus and vertigo as above described are in no sense characteristic of disease of the labyrinth; the same phenomena occur in cerebellar abscess.

Upon the removal of the semicircular-canal system, the vestibule, and the lower half turn of the first cochleal whorl, nystagmus, vomiting, vertigo, disturbed equilibrium, and intense high-pitched hissing noise, all of which are distressing before operation, may immediately cease.

Following the removal of the major portion of the labyrinth, conjugate deviation of the eyes may occur, the direction assumed being upward and outward toward the operated side, as if the eyes were attempting to see the labyrinthine lesion.

Following the removal of the deep portion of the petrous pyramid, it may be noticed, upon the patient's emergence from anæsthesia, that both pupils are dilated to an extreme degree. This dilatation probably results from disturbance of the sympathetic, at the deep, apical portion of the pyramid. The pupils, though dilated *ad maximum,* may react both to accommodation and to light. The dilatation gradually disappears after the lapse of several weeks.

Following the exenteration of the petrous portion of the temporal bone, probing or pressure in the immediate vicinity of the stump of the auditory nerve may produce vertigo, nystagmus, and the subjective phenomenon of intense noise, which noise is referred to the involved ear.

Following the exenteration of the labyrinth, the patient may be exceedingly sensitive to noise and to loud musical sounds. The sense of harmony may at first be lost, and then, after several months, regained. The patient, if subjected shortly after operation to loud musical sounds (as the playing of the piano), may become intensely dizzy.

Following the removal of the entire labyrinth, tinnitus sometimes persists in the involved ear; its character, however, may completely change; and, even when the tinnitus before operation is intense and of high pitch, it may assume a low, buzzing, inoffensive character after operation. Later, the tinnitus may entirely cease.

When the facial nerve is exposed throughout its entire circumference, we may with confidence look for paralysis upon the patient's emergence from anæsthesia. The paralysis deepens, and in forty-eight hours becomes complete. It persists for four or five months, even though no injury is done the nerve other than to expose it to the fluids of the wound; and yet, although the reaction of degeneration may appear, the face, under massage and with time, nearly regains its normal expression.

The facial nerve is structurally very delicate. It should therefore be protected by sterile vaseline and subjected to no pressure by the packing; and besides, the dressing should be changed sufficiently often to keep the cavity clear of pus.

Subsequently to the operation, meningitis may occur. It manifests itself in from forty-eight to seventy-two hours. It is characterized by the usual features, with the exception that the sensorium is remarkably clear, till near the end. The termination comes rapidly. Though the post-mortem examination may show a diffuse lepto-meningitis, the cerebellar fossa is the site of greatest pathological activity.

As a result of the too rapid drainage of the cerebro-spinal fluid from the cerebellar fossa the following symptoms may appear: a small, rapid, irregular pulse; embarrassed respiration, which may assume a Cheyne-Stokes character; an anxious, concerned expression, with cold extremities and pinched, livid features; and marked restlessness. These symptoms may be of such alarming character that death seems imminent, but with a lessening of the escape of cerebro-spinal fluid the whole picture may in the course of a few hours so completely change that the patient appears quite normal. These symptoms are undoubtedly due to a too rapid drainage of the water-bed of the brain, whereby the important nerve centres at the base, having lost their elastic support, sink and are brought into undue contact with the floor of the skull. The quick disappearance of these symptoms upon the cessation of the escape of cerebro-spinal fluid forbids any other than a mechanical interpretation.

Following operations upon the labyrinth, large quantities of sugar and acetone may appear in the urine, and the clinical picture of diabetes may rapidly develop.

Where the destructive process in the labyrinth has existed for a long time and the irritation stage is passed, the organ is, so to speak, functionally silenced and shows no sign of life. Its exenteration is followed by no disturbance whatever of equilibrium; vomiting, vertigo, and nystagmus do not occur, as the compensating factors, whatever they may be, have made good the deficiency.

After an operation upon the labyrinth, the pulse may be both irregular and rapid, and this disturbance may take place independently of the loss of cerebro-spinal or labyrinthine fluid. The condition soon rights itself.

PYOGENIC DISEASES OF THE BRAIN, OF OTITIC ORIGIN.

By HENRY OTTRIDGE REIK, M.D., Baltimore, Md.

I. GENERAL REMARKS WITH REGARD TO THE ETIOLOGY AND PATHOLOGY OF BRAIN ABSCESSES.

When the prevalence of purulent disease of the ear, the character of the micro-organisms commonly associated therewith, and the seemingly inadequate and vulnerable nature of the anatomical structures that are located between the tympanic cavity and the brain, are considered, it is rather more surprising that the delicate intracranial tissues are so seldom invaded than that they should be occasionally involved in an extension of the aural affection. In what percentage of all the cases of suppurative otitis media intracranial complications do arise it is impossible to determine with any degree of accuracy. An imperfect idea may be obtained from the following statistics:

Dr. Thomas J. Harris,* in a review of 12,744 cases of suppurative ear disease applying for treatment at the Manhattan Eye and Ear Hospital, New York, found that there were recorded 60 cases of intracranial disease, divided as follows: 30 of meningitis; 23 of lateral-sinus thrombosis; 6 of cerebral abscess, all in the temporo-sphenoidal lobe; and 1 of cerebellar abscess.

From the annual report of the Massachusetts Charitable Eye and Ear Infirmary for 1907 I obtained the following very interesting figures:—The total number of new ear patients applying to the out-patient department during that year was 8,919. Among this number of patients there were diagnosed 1,120 cases of acute and 2,028 of chronic suppurative otitis media, a total of 3,148 cases of purulent middle-ear disease. From these, 304 of the acute and 145 of the chronic cases were admitted to the house, and 23 of the acute type and 14 of the chronic developed intracranial complications; in several of the latter group more than one complicating lesion was present. Thus, there were associated with the acute middle-ear diseases 6 cases of meningitis; 1 of cerebral abscess; 1 of cerebellar abscess; 7 extradural abscesses, 5 of which were perisinous; 1 subdural abscess; and 7 cases of lateral-sinus thrombosis. Complicating the chronic middle-ear suppurations there were 9 cases of meningitis; 4 of cerebral abscess; 1 of cerebellar abscess; 4 extradural abscesses, 2 of which were perisinous; and 2 cases of lateral-sinus thrombosis.

The statistics from these two excellent and largely attended special hospitals may be taken to show not only the frequency with which intracranial lesions

* Laryngoscope, 1905, vol. xv., p. 536.

result from, or occur in the course of, otitic disease, but, furthermore, they tend to demonstrate the relative frequency of the different complications. As might be expected, from a consideration of the anatomical factors, extradural abscess heads the list, with meningitis and sinus thrombosis following in the order named, while cerebral abscess occurs about twice as often as abscess of the cerebellum—the least commonly observed complication.

To ascertain the part performed by otitis in the causation of these intracranial diseases, as compared with other agencies, we must turn to the reports of the large general hospitals; but even then it is difficult to arrive at satisfactory conclusions. While these institutions receive any patients suffering with these diseases, regardless of the causative factor, both the public and the profession have been undergoing a process of education on the importance of neglected ear disease, and, in consequence, there has been of late years a growing tendency to send patients with brain diseases of otitic origin directly to the special hospitals. Again, it is sometimes difficult to distinguish the real cause of a brain lesion. It does not necessarily follow, for instance, that meningitis occurring in a patient who has for years been subject to purulent otitis media, is actually the result of that old affection. As bearing upon this matter, Whitehead,* in a very instructive paper on the complications of temporal-bone disease, based upon a study of the work performed at the General Infirmary at Leeds, England, during the last fifteen years, makes this very significant statement: "There was an antecedent history of chronic otorrhœa in 2 out of the 33 cases of meningitis; in 17 out of 20 cases of sinus thrombosis; in 20 out of 21 cases of cerebral abscess; in 13 out of the 15 cases of cerebellar abscess; and in 1 of the 2 cases of combined cerebral and cerebellar abscess." These figures would seem to be rather high as regards brain abscess if we are to judge by the indefinite, but previously accepted, statements of the text-books. The general consensus of opinion has appeared to be that something more than fifty per cent of all cases of brain abscess were of otitic origin; the remainder being mainly the result of traumatism, with a few due to metastasis from purulent disease in other parts of the body.

Viewing the question from still another standpoint—that of the death-rate of purulent otitis as compared with the death-rate from all diseases treated in the large general hospitals—Gruber † found, in the post-mortem records of the Vienna General Hospital, 232 deaths from otitic intracranial disease among 40,073 autopsies (0.58 per cent); and Pitt‡ found 57 deaths of this sort in 9,000 autopsies at Guy's Hospital, London (0.68 per cent).

The relationship between the site of the brain lesion and the portion of the ear diseased is a matter of some importance, both from the pathological and from the diagnostic point of view. The most common seat of otitic cerebral abscess is the temporo-sphenoidal lobe, and in the majority of instances the route of invasion can be traced through the roof of the tympanum or antrum mastoideum to the affected portion of the brain. Not infrequently a connecting stalk can be found.

* Archives of Otology, 1906, vol. xxxv., p. 427. † Archives of Otology, 1896, vol. xxv., p. 401.
‡ Brit. Med. Jour., 1890, vol. i., p. 643.

Barker* states that the most usual seat is the middle or posterior part of the temporo-sphenoidal lobe, and that nine-tenths of the abscesses will be found within a circle having a radius of $\frac{3}{4}$ inch, whose centre lies $1\frac{1}{4}$ inch above and the same distance behind the centre of the external auditory meatus.

Cerebellar abscesses, on the other hand, are almost invariably associated directly with purulent disease of the posterior mastoidal cells, or with an extension of the middle-ear necrosis through the labyrinth; the route of infection being through the vestibule and internal auditory meatus or the ductus cochlearis. Occasionally, however, both cerebral and cerebellar abscesses occur at points remote from the most seriously diseased part of the tympanum or antrum, and in these cases no direct connection between the lesions can be determined, the brain having probably become infected indirectly by way of the blood or lymph channels. Extradural abscesses, in the great majority of cases, are located directly over the tegmen tympani or tegmen antri, or, in a small number of cases, along the sigmoid portion of the lateral sinus—the so-called perisinous abscesses.

Conversely, it may be said that a middle-ear suppuration which appears to be most active in the epitympanum is favorable to the production of extradural abscess, meningitis, or cerebral abscess, and that those cases of purulent otitis which show more marked involvement of the mastoid region, as evidenced by greater tenderness at the tip or along the posterior border of the mastoid process, are prone to produce perisinous abscesses, lateral-sinus thrombosis, or cerebellar abscess.

The majority of the brain affections of otitic origin result from the neglect of chronic suppurative otitis media. Less often does the acute type of purulent otitis invade the cranial cavity. Any case of persistent or recurrent suppuration of the middle ear is a menace to life, and, while no one can say in what particular instances such an otitis will prove dangerous, the possibility of its causing intracranial complications must always be borne in mind. Experience seems to have taught that those cases of otitis which originated in an attack of scarlet fever or measles are the most virulent. A purulent inflammation of the middle ear may persist for many years without causing serious disturbance of health or destruction of any tissue beyond the confines of the tympanic cavity, yet there is no moment in all these years when it may not flare up into an active process that will be extremely difficult to check or to control. What should induce such renewed activity or precipitate the appearance of dangerous features is often unascertainable. The influence of climate may at times be felt, for exposure to severe cold may render the tissues more susceptible to the ravishing onslaught of micro-organisms and enable the latter to make more rapid progress. The occurrence of a fresh infection, as by the accidental admission of unclean water into the ear, or the onset of some septic affection, may excite a dangerous exacerbation of the otitis.

Pyogenic micro-organisms are the active agents in the causation of these brain diseases, and the most prominent among them are the Streptococcus

* London Lancet, 1887, vol. ii., p. 1175.

pyogenes, Staphylococcus pyogenes aureus, and the pneumococcus, although a great variety of other organisms are included in the list of those occasionally found. I have seen one case of extensive extradural abscess, with a most foul-smelling pus, from which the Bacillus coli communis was obtained.

Finally, the anatomical character of the temporal bone may be considered as a predisposing factor; the pneumatic bones whose cells communicate freely with one another melting away more readily under a necrotic process than the diploëtic or eburnated specimens. (Fig. 392.) When the petro-squamosal suture, which passes through the roof of the tympanum, remains open, as it probably does for a considerable period of time in some children, the dura may rest in contact with the tympanic mucous membrane, and the opportunity is then

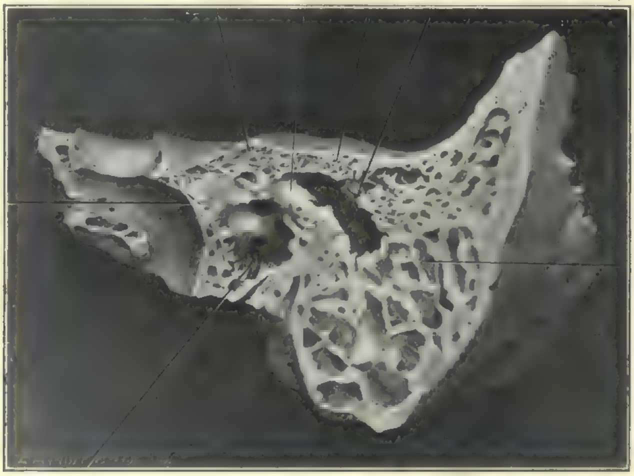

Fig. 392.—Pneumatic Type of Mastoid, with Numerous Communicating Cells. (Original.) Note the thinness of the plate of bone that separates the brain from the cavities of the middle ear—a degree of thinness that explains in large part the ease with which a process of suppuration may extend from the tympanum or the antrum to the cerebral cavity.

afforded for the extension, through this channel, of infection from the middle ear to the cerebral cavity. I have recently come into possession of an adult skull which shows that this suture sometimes remains pervious throughout life. (Fig. 393.)

In the study of the etiology of otitic brain disease, perhaps the most important consideration for the medical profession fully to recognize is that such diseases are almost entirely preventable. If every case of suppurative otitis media, whether acute or chronic, but particularly the latter, were brought under proper care, and skilfully, patiently, and persistently treated until the aural disease was cured, there would be very few instances of purulent brain disease, and those only of the fulminating acute type which advance so rapidly that medical skill is powerless to conquer them.

Whatever the morbific excitant to inflammation may be, there is always, in the ear as elsewhere, a condition of local tissue degeneration, followed by alteration in the circulation and by exudation. The first effect of a localized tissue injury is an active hyperæmia of the part, on account of the dilatation of the lumen of its blood-vessels, and this particular dilatation may be the result either of stimulation of the vaso-dilators or of paralysis of the vaso-constrictors. With the increase in calibre of the vessels there are a coincident slowing of the blood current and the commencement of a pathological exudate; as the flow diminishes in speed the solid elements of the blood, in compliance with physical laws, must leave the centre of the stream and accumulate at its periphery, that is, along the walls of the blood-vessels; and as these vessel walls have at the same time become changed in structure, so as to show an increased permeability, the active corpuscular elements, together with red blood corpuscles and the serous fluid, pass out through the cell interstices. These migratory white blood corpuscles, chiefly the polynuclear forms of leucocytes, the red blood corpuscles, the extravasated serum, and the degenerated and desquamated tissue cells constitute the inflammatory exudate.

In a cavity of such limited space as the tympanum, containing delicate structures of great importance to the perfect functioning of a sense organ, even such a simple inflammatory exudate as that above described may occasion serious damage. When pus-producing bacteria are at work there are special and characteristic differences in the manufacture of the exudate and greater danger of serious interference with the organ and its neighboring structures. Pus cells accumulate in great numbers, and, instead of the deposition of fibrin, there is a tendency to liquefaction of the exudate and of the necrotic tissue, through the solvent action of the pyogenic germs. As the result of chemotaxis the leucocytes leave the blood-vessels of the inflamed area to meet the invading bacterial poisons. Micro-organisms of an especially virulent type, or a too numerous collection of less dangerous ones, may rapidly destroy a mass of white cells, and it is these débris of the battle that constitute the pus of purulent affections. The tissue cells may also take on the phagocytic action of the leucocytes. Under the microscope this yellowish-white exudate is seen to consist of serum, leucocytes, often containing bacteria within their substance, and the degeneration products of dead leucocytes and tissue cells.

With the destruction of the epithelium and superficial portions of the mucous membrane a condition known as ulceration is produced, and this is probably constantly associated with suppurative otitis media; the only exception might be in the few cases of acute inflammation, of very short duration, in which the slight amount of pus that is formed makes its exit through the tympano-pharyngeal tube, or in which the active seat of purulent inflammation is rapidly transferred from the tympanum to the mastoid cells without preceding erosion of the tympanic membrane. The extent of the ulcer must vary considerably, involving in some instances but a small point on the covering of one of the ossicles, or on some part of the lining of the tympanic walls, in other cases extending over a comparatively large area of these tissues. Furthermore, the depth to which this loss of cellular substance, or tissue necrosis, extends in the tympanum is a matter for particular consideration. At no point is the mucous membrane covering the tympanic walls very thick, and over some portion of the ossicles it is no more than an endothelial coat over a single layer of cells that serves as a periosteum, with an insignificant amount of fibrous substance between them. Some of these thinly covered spaces, particularly on the incus, are also especially prone to necrosis because of their poor nutrition—due to a limited blood supply—under normal conditions. When deprived of the protection of its periosteal coat the bone readily succumbs to the destroyer, and necrosis of the ossicles is a common feature of prolonged suppurative tympanic inflammation.

More frequent still is the ulceration or erosion of the membrana vibrans. This portion of the external wall of the tympanum is the weakest of all and the

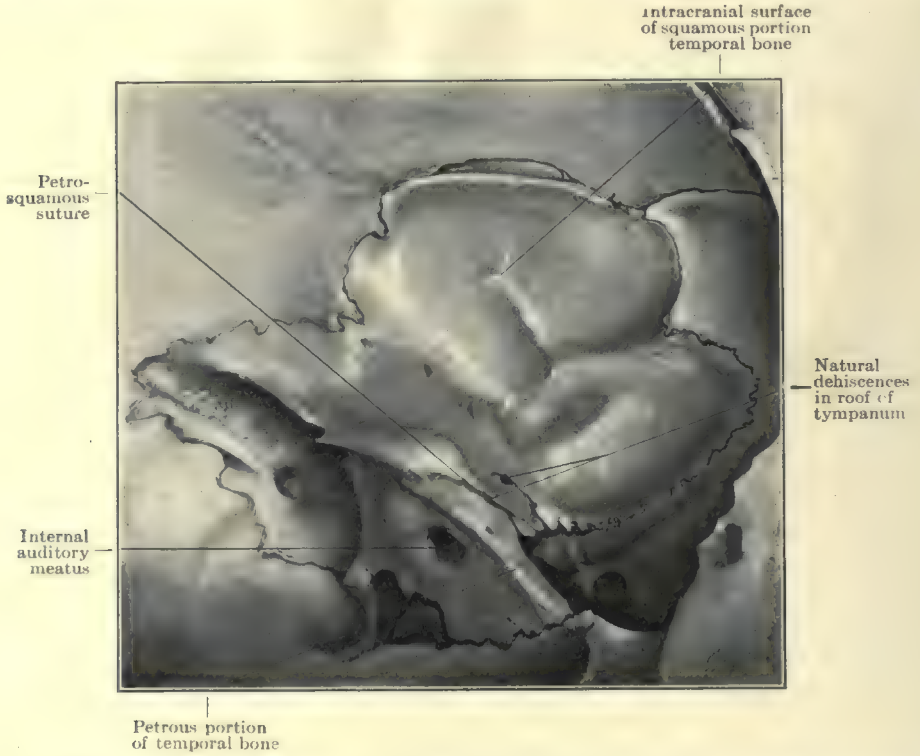

Fig. 393.—An Unusual Specimen of Adult Skull, Showing Sutural Lines on the Inner Surface. (Original.) The petro-squamous suture, passing through the tympanic roof, is open, and beside it there is a long slit-like dehiscence of the posterior part of tympanic roof that permits passage of a probe into either tympanum or antrum.

only one that can give way before the pressure of an accumulating exudate. With the formation of any considerable amount of pus within the tympanum the intratympanic pressure on this membrane gradually increases, and, as it becomes greater than the external air pressure, a bulging outward of some portion of the membrane follows. Diminution of the pressure through the escape of excretions by way of the tympano-pharyngeal tube is sometimes possible, but is generally prevented by the blocking of this channel incident to swelling of its lining mucous membrane. In consequence of decreased viability of that portion of the membrane which is subjected to the greatest pressure from within, rendering it more liable to ulcerative perforation, spontaneous rupture of the weakened area takes place, and through this perforation the pus exudes into the external auditory canal.

With the occurrence of spontaneous perforation of the membrane, or the establishment of drainage by incision of that structure, the inflammation usually subsides, the purulent secretions flow away as rapidly as they are formed, the

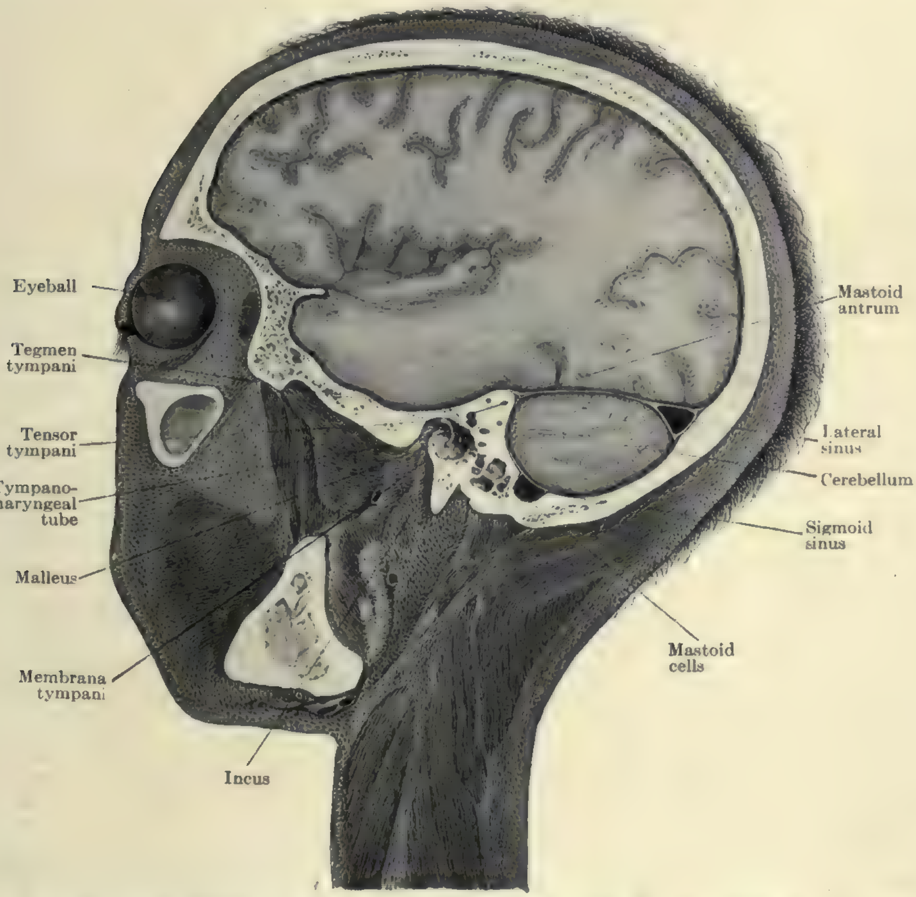

FIG. 394.—Antero-posterior Section of a Frozen Head, through the Tympanum. (Original.) The picture is intended to illustrate the several routes by which purulent disease may extend from the middle ear, and to show the relationship of the tympanic cavity to important neighboring structures.

patient rallies sufficient forces to destroy the bacteria, and a process of repair begins. In many cases, however, this desirable result does not follow. Owing to a debilitated system, to anatomical conditions favoring the retention of purulent secretions, or to virulence of the attacking micro-organism, the suppuration continues and a chronic otorrhœa is the result. A long-continued process of this sort destroys the mucous membrane and may cause necrosis of the ossicles or the bony walls of the tympanum and its communicating cavities.

Could a suppurative inflammation of the middle ear always be confined to the mucous membrane lining the tympanum, or even if it should involve only the ossicles, the disease would have no mortality and would be of interest prognostically only in so far as it might possibly impair the function of the sound-transmitting apparatus of the organ of hearing. Surrounded as the tympanum is, however, by organs and structures more important to life, the problem, when an inflammation breaks through the tympanic bounds, becomes a far more serious one than that concerned in the effect it may have on the hearing power. When suppurative otitis media starts on a destructive tour it may invade the mastoid process and, by an extension in one of several directions, produce mastoiditis, lateral-sinus thrombosis, extradural abscess, meningitis, or cervical, cerebral, or cerebellar abscesses. (Fig. 394.) It may perforate the internal wall of the tympanum and set up a purulent inflammation of the labyrinth, with the possibility of extension to the cerebral cavity through the internal auditory canal, the ductus cochlearis, or the ductus vestibuli; it may erode the bony sheath of the facial nerve and cause paralysis of the muscles supplied by that nerve; or, through the medium of the lymphatic or venous channels, it may cause a systemic infection.

It is interesting to note that some of the serious complications of otitis media are made possible through Nature's effort to supply new structures for the replacement of those removed by suppuration. Granulation tissue, springing from some ulcerative point, may readily assume the nature of a polypoid growth, and these polyps, when exuberant, by pressure on neighboring structures or by favoring the retention of unhealthy excretions, add to the seriousness and chronicity of the original disease. Secondly, wandering epithelial cells, or the hyperplasia of cells from the dermal layer of the membrane at the margin of the perforation, or from ulcerative areas in the lining of the tympanum, may lead to the development of cholesteatomatous accumulations through the excessive growth of these misplaced cells. Occasionally these become massed together into a tumor-like mass, producing increased damage by erosion of the surrounding structures.

In what proportion of cases the mucous membrane of the antrum mastoideum is involved, by direct extension, in the inflammation of the tympanic cavity, has long been a matter of speculation. So good an authority as Politzer believes that the antrum is practically always involved, and, whether this be true of the acute form of otitis media or not, it is certainly reasonable to assume that the antrum is concerned in all cases of chronic purulent otitis. The same process of tissue infection and degeneration goes on here as has been described for the tympanic mucous membrane, and the speed with which an inflammation progresses depends upon the virulence of the invading micro-organism and the density as well as the resisting power of the bony structure. By a process of molecular disintegration and ulceration the abscess cavity grows as the necrosis advances. The character of the bony framework probably determines in a large measure the direction in which the disease process shall advance.

Should the bony roof of the tympanic cavity or of the antrum be very thin or of cellular structure, while the general mastoid structure is that of the diploëtic or eburnated type, conditions favor erosion into the cerebral cavity in this direction. On the other hand, should the thin-walled cellular spaces of the mastoid process invite extension of the necrosis posteriorly, conditions are favorable for invasion of the cerebellar cavity in the region of the sigmoid sinus. Extension of the necrotic process through the internal wall of the tympanum, by way of the oval or the round window, or, less frequently, through the semicircular canals or the cochlea, occasionally takes place, producing first an inflammation of the labyrinth and then intracranial disturbance by extension through the ducts of the vestibule or cochlea or by way of the porus acusticus internus.

II. GENERAL SYMPTOMATOLOGY AND DIAGNOSIS OF INTRACRANIAL COMPLICATIONS OF SUPPURATIVE OTITIS MEDIA.

The differential diagnosis of the intracranial complications of suppurative otitis media is a matter of the gravest concern and yet one that is attended by great difficulties and fraught with the highest degree of uncertainty in every instance. When, as not infrequently happens, two or more of the possible complications occur coincidently, the confusion naturally existing is certainly worse confounded. Only by the closest attention to every feature of the individual case, can we hope to make definite diagnoses. At all times, too, the fact must be kept in mind that atypical cases of these diseases are far from rare. Then, again, it must be remembered that, in very many instances, by the time the picture has become so clear as to constitute a typical clinical entity, the most favorable moment for treatment has passed away. The successful handling of the purulent otitic brain affections depends upon the ability to recognize such disorders in their earlier stages and to apply promptly the required surgical measure for relief. In view of the fact that even the most skilful observers are oftentimes unable positively to differentiate these conditions during the initial stage of an illness, it sometimes becomes necessary, for the best interests of the patient, to operate when the diagnosis is uncertain,—in other words, to do what may be called an exploratory operation, for the purpose of perfecting the diagnosis by actual inspection of the parts under suspicion. Such an aid to diagnosis is not only justifiable, but probably should be employed much more frequently than has been the custom in past years. Many cases of brain abscess or of lepto-meningitis might have been averted had the temporal bone been opened in the stage of uncertain symptoms,—in other words, at a time when the cranial floor had probably just been perforated and the dura was undergoing attack. Practically every case of extradural abscess gets well if exposed and drained. Likewise the initial stage of sinus thrombosis is usually a phlebitis produced by an attacking perisinous abscess, and exposure of the sinus at that time is not only favorable to eradication of the abscess and neighboring mastoid disease, but may, and probably will, avert a septic thrombosis of the vessel. No surgeon hesitates to-day about opening the abdominal cavity preliminary to a definite diagnosis; the recognition of the fact that some intra-abdominal disturbance of a serious character exists is accepted as sufficient to warrant an exploration. There is no good reason why such a rule should not be applied to the cranial cavity, since modern surgery has made it quite as safe to explore this region.

It is therefore a matter of great importance to ascertain, if possible, the earliest indications of invasion of these several vital structures—the meninges, the cerebrum, the cerebellum, and the sigmoid portion of the lateral sinus. To that end, it seems best to consider the intracranial complications of suppurative otitis media separately; it being understood, from the heading of this section, that evidences of middle-ear disease are or have been present. It may be well to call attention here to the very important fact that a long-existent discharge from the ear may have ceased coincidently with, or just prior to, the onset of symptoms pointing to some intracranial disease, and that the appearance of such symptoms without otorrhœa necessitates inquiry regarding any previous ear trouble. As a consequence of his sufferings, or in the excitement attending a sudden illness, the patient or the friends may neglect to mention the previous aural disease. In the light of our knowledge that otitis media is by far the most common cause of such symptoms, the physician should always examine for evidences of existing or past purulent disease of the tympanum. The possibility that an acute infection of the middle ear may involve the deeper structures without previously causing a rupture of the tympanic membrane should not be overlooked. The writer has reported several cases of mastoiditis in which the purulent disease passed through the tympanum without causing perforation of the drum head, and he has operated upon one case of extradural abscess in which the collection of pus was located directly over the antrum,—the only part of the mastoid process which showed any evidence of being diseased,—while at the same time the tympanic membrane remained intact. Holt* has called attention to the frequency with which this condition obtains, particularly in young children. He collected 32 cases of brain abscess occurring in children under 5 years of age; 13 were under 1 year of age, 9 of these being under 6 months and 5 under 3 months. Concerning the point at issue he says: "In three of my own cases no discharge from the ear has preceded the cerebral symptoms; although in 1 there was an ear discharge during the course of the brain abscess, and in 2 others pus was found in the middle ear at autopsy. These last cases deserve more than passing notice; the frequency with which pus is found in the middle ear in very young children, particularly infants who have died from various forms of disease, has only recently been appreciated. Kessel found it in 85 out of 108 consecutive cases examined, Rasch in 45 out of 60 cases, and Hartmann in 35 out of 47 autopsies, in 28 of which it was double. The majority of the above patients were infants, and in a large percentage of them no symptoms of otitis had been noted during life. In this condition, it seems to me, is to be found an explanation not only of the origin of brain abscesses which

* Archives of Pediatrics, 1898, vol. xv., p. 81.

develop without exciting cause, but also of very many of the cases of acute meningitis for which no etiology can be found."

Brain lesions resulting from acute suppurative otitis media usually follow so closely upon the onset of a primary disease that the relationship between the two is quite apparent. The earache probably did not, as is usual in uncomplicated cases, cease with the rupture of the tympanic membrane and the outpouring of purulent secretion from the tympanum; the febrile condition persisted; the general malaise incident to a continued illness increased; and the symptoms appeared in sequence indicative of a complicating extension, according to the portion of the brain attacked.

But the majority of all the mentioned intracranial affections result from chronic purulent otitis media of a destructive type, and in these cases certain symptoms are common to them all. Thus, very many patients, at the time when the surgeon is consulted, give the following clinical history:—An otorrhœa, possibly originating in an attack of one or other of the exanthematous fevers, had existed for a prolonged period, but the patient had become so accustomed to the discharge that it gave him no concern. Suddenly, as a result probably of reinfection, symptoms of acute inflammation arose. There was pain in the ear and over the temporal region, accompanied by a general febrile condition. The mastoid region became tender to the touch, and its covering tissues were œdematous. The discharge from the ear may have increased in amount, or have changed in character, or have ceased entirely. From this point onward the symptoms observed vary according to the route traversed by the suppurative inflammation and also according to the nature and extent of the tissues attacked. The occurrence of a sharp chill at this time is strongly suggestive of intracranial invasion, but does not point solely to any particular one of the different pathological conditions which are encountered within the cranial cavity, and which—with the exception of infective sinus disease, which has already been discussed in the article preceding this—we shall now consider in a separate section.

III. LEPTOMENINGITIS; EXTRADURAL, INTRADURAL,* CEREBRAL, AND CEREBELLAR ABSCESSES.

General Etiology and Pathology.—Perforating erosion of the tympanum and mastoid is not generally a rapid process, nor does it usually form a part of an acute inflammation in those regions. Most frequently it is the result of chronic, slowly progressing infection, and nature has every opportunity to prepare whatever resistance is in her power. Advancing necrosis is always preceded by a zone of inflamed and infiltrated tissue. It happens, therefore, that by the time perforation of the bony tegmen is completed, irritation of the adjacent dura mater has led to the outpouring of a plastic exudate and even to the formation

* The term "intradural" seems, on the whole, to be preferable to that which is so commonly employed—viz., "subdural." (See the foot-note relating to the use of this term on p. 179.)

of a resisting wall of granulation tissue. Such a barrier may prove sufficient to obstruct the devastating process and even to assist in removing inflammatory débris. By fibrous organization of the exudate beyond the area of necrosis the dura becomes adherent to the healthy bone, and the condition is known as a limited external pachymeningitis; if pus collects under the dura, in this circumscribed, walled-off area, it constitutes an extradural abscess.

More extensive inflammation of the dura or invasion of the pia and arachnoid may result in a direct spreading of the disease to contiguous parts, and the issue will be a more diffuse pachymeningitis or a leptomeningitis. In a case of meningitis of otitic origin it is not always possible to demonstrate the pathway along which the necrotic process has travelled from the tympanum to the meninges, but an indirect route may often be traced through infective thrombosis of the small vessels running from the diseased bone to the cerebral sinuses. The infection may also take place through septic emboli carried some distance from their source. Another mode of infection of the meninges,—one which occurs especially in childhood,—is by the filtration of pus from the mastoid cells through the still open petro-squamosal suture. Pachymeningitis extends slowly and without serious symptoms until other and more delicate structures are involved. Leptomeningitis, on the other hand, spreads rapidly because of the web-like composition of the arachnoid and the great vascularity of the pia mater. It is of much more serious import than inflammation limited to the external brain covering, and is soon complicated by infection of the cerebro-spinal fluid and the involvement of the cranial and spinal nerves. The cortex of the brain and cord is seldom involved, but in some cases areas of œdema and softening of the superficial layers may be found, with some infiltration with pus cells, constituting a superficial encephalitis, or ulceration of the brain. This local destruction of brain tissue may be entirely on the surface or take place just below the cortex. In the latter instance, if resulting from an embolic infection, it may be limited to the domain of one arterial branch.

Summary of the Important Symptoms of Intracranial Complications of Purulent Otitis Media, and their Diagnostic Significance.—To summarize briefly those symptoms which may be helpful in determining the exact location of the brain affection, it may be said that:—

(*a*) Extradural abscess and pachymeningitis present no characteristic symptoms other than, possibly, an aggravation of the usual evidences of mastoiditis, and the condition is more frequently discovered during operation than definitely diagnosed beforehand.

(*b*) Leptomeningitis has, for its most characteristic symptoms, a persistent high fever; contamination of the cerebro-spinal fluid; and the presence of epithelial cells or micro-organisms in the fluid obtained by lumbar puncture.

(*c*) Intradural abscess and superficial encephalitis cannot be distinguished from brain abscess prior to operative intervention.

(*d*) Brain abscess is suggested by a low pulse-rate, low temperature (the latter occasionally touching a subnormal point), and projectile vomiting. An aphasic condition localizes the disease in the temporo-sphenoidal lobe of the left hemisphere, while inco-ordination of the muscles and vertigo point rather toward the cerebellum.

(*e*) A fluctuating temperature curve, that ranges between normal and a fever of high grade, whether associated with chills and sweats or not, points to thrombosis of the sigmoid portion of the lateral sinus.

Leptomeningitis.—Symptomatology and Diagnosis.—The diagnostic evidences of this complication are much more striking and characteristic than are those which belong to extradural abscess. Following upon the symptoms of middle-ear disease and possibly mastoiditis, the earliest symptoms are apt to be those of irritation of the meninges. Among such symptoms may be enumerated vertigo, vomiting, insomnia, hyperæsthesia of the nerves of sensation, stiffness of the muscles of the neck, and irregular pupillary action. No single symptom of the group can be taken as positively pointing to meningitis, nor indeed can the entire group, when present, be considered pathognomonic; all of them may be associated with cerebral or cerebellar abscess. Vertigo may be accounted for on the ground of labyrinthine disease and is frequently observed in simple, apparently uncomplicated, otitis media. Nausea and vomiting occur with so many and so varied general disorders that little importance can be attached to them as evidences of meningeal disturbance. Headache is almost invariably present, but is not so intense as that of pachymeningitis or of brain abscess. Paralytic symptoms, such as dilatation of the pupils, paralysis of the external muscles of the eyes, facial-nerve paresis, and hemiplegia, are strong evidences of meningitis, but do not appear until the disease is well advanced. In the same way, optic neuritis (choked disc), when observed, is a late symptom and one for which the physician cannot afford to wait before instituting treatment. Kernig's symptom (inability to extend the knee while in the sitting position) is a fairly constant one and should be sought for in every suspected case.

Among the early symptoms perhaps the most reliable, if taken in connection with those suggestive of meningeal irritation, are a high temperature, marked leucocytosis, with relatively high polymorphonuclear percentage, and the changed character of the cerebro-spinal fluid. The characteristic temperature chart of leptomeningitis shows continuous high fever. There are, perhaps, variations between the morning and evening readings, but they are not of so marked a character as those which are associated with infection of the blood stream. The leucocyte count is generally high, much higher than in ordinary mastoiditis and usually higher than that commonly witnessed with sinus thrombosis or brain abscess. And here, as with purulent disease in other parts of the body, the leucocytosis is one in which there is a marked increase in the polymorphonuclear cells, the relative percentage being eighty or more. A study of the fluid obtained by spinal puncture gives the most positive information regarding the state of the inner layers of the meninges. The method of tapping the spinal canal in the lumbar region, to secure cerebro-spinal fluid for examination, was first suggested by Quincke, but we are more indebted to Wentworth,*

* Trans. Amer. Pediatric Soc., 1896, vol. viii., p. 84.

whose careful investigations on this subject are deserving of the highest praise, for having shown that "the normal spinal fluid is absolutely clear and free from all cellular elements and fibrin," and that "the slightest cloudiness present at the time when the fluid is withdrawn, and caused by the presence of cells in the fluid, and by the formation of fibrin in the fluid after it has stood for several hours, are pathognomonic of an inflammatory exudation in the meninges, and are never absent in cases of meningitis." (See also p. 199.)

The signs of a more advanced stage of meningitis are extreme restlessness and irritability, delirium, convulsions (localized or general), and retraction of the head with rigidity of the neck muscles. In children this last symptom occasionally reaches the degree of marked opisthotonos. Paralysis of the third, fourth, or sixth nerves, partial or complete, may be present, and swelling of the optic papilla, with engorgement of the retinal vessels, may be observed ophthalmoscopically. Lesions of all these nerves are the result of intracranial pressure from the accumulating exudate and consequently are not often seen until the disease is far advanced. Coma and the Cheyne-Stokes type of respiration point to approaching dissolution.

Prognosis and Treatment.—Leptomeningitis is recognized by all as the most dangerous of the otitic brain complications. That it is not utterly hopeless is proven by the fact that a number of recoveries have been reported as following operative intervention in what appeared to be desperate cases. If the inflammation is limited to the base of the brain, removal of the underlying purulent aural focus, and drainage through an incision in the dura, give a fair hope of recovery. If, however, the arachnoid of the convex surface of the hemisphere be extensively involved, even drainage is not very promising. In the early stage of the inflammation, while the exudate is still of a serous character, lumbar puncture, repeated as often as may be necessary, may prove beneficial by reducing the intracranial tension and removing a considerable amount of infective material. When, after this procedure is employed for diagnostic purposes, an improvement in the patient's condition mainfests itself, the physician should be encouraged to repeat the operation.

The surgical measure most urgently demanded in otitic meningitis is, primarily, eradication of the middle-ear disease, with subsequent exposure and examination of the meninges. In the course of the mastoidectomy a careful search should be made for any carious track leading into the cranium, and, if a fistula should be found in the tegmen, the tympanic or antral bony roof should be removed to a sufficient extent to afford a satisfactory view of the base of the brain. Incision of the dura at that point is quite proper if it is evidently diseased, but, on the other hand, if the dura over the tympanum and antrum is apparently healthy, it is perhaps wiser, as a general rule, to leave it intact and to make a second opening into the cerebral cavity directly above the external auditory meatus, through the squamous portion of the temporal bone, and to open the dura there; thus avoiding the possibility of directly connecting healthy brain tissue with a region known to be infected. A gauze drain may be inserted into the intradural space, whether the exudate be serous or purulent.

In some cases diagnosed as meningitis nothing abnormal is discovered about the superficial cortical meninges beyond the fact that they are abnormally tense; this increased intracranial tension being probably due to distention of the lateral ventricle, from an internal serous meningitis. In a case of this nature Keen's* operation of tapping the ventricle and inserting a gauze drain may be performed, in addition to employing lumbar puncture as a therapeutic measure. Keen also made the suggestion that, if the exposed dura is tense, elastic, and bulging, abscess or tumor may be present; but that if, in addition to these symptoms, there is cerebral pulsation, a diagnosis of ventricular dropsy is more likely to prove correct.

No satisfactory statistics as to the percentage of recoveries from the operative treatment of purulent meningitis are at present obtainable.

Extradural Abscess.—While this, if understood to include the so-called perisinous abscess (a collection of pus between the inner table of the mastoid process and the outer, dural wall of the lateral sinus), is by far the most frequent complication of purulent otitis, it is without definite and characteristic symptoms. In consequence of this fact, it is much more often encountered during the operative treatment of a pronounced mastoiditis than sought for as the result of positive preoperative diagnosis. Generally, whether in connection with an acute cr in connection with a chronic otitis, the symptoms noted will be simply those of an aggravated mastoiditis: marked pain behind and deep in the ear, possibly with waves of pain radiating over the temporal region; tenderness on pressure over the mastoid surface, particularly over the antrum or along the posterior border of the processs; in some instances, localized tenderness above and slightly in front of the auricle, on a line with the temporal ridge; high fever and a leucocytosis; possibly postaural swelling and drooping of the postero-superior wall of the cutaneous external auditory canal, due to inflammatory œdema. In addition to these symptoms, there are a few which may possibly indicate the existence of a pachymeningitis or an extradural abscess. A chill, or chilly sensations, may announce irruption of the disease into the cranial cavity, and, if the chill be repeated or if the chilliness continue, the symptom is especially suggestive of irritation of the dural covering of the sinus. Diffuse and severe headache is almost always present when there is a collection of pus under the dura; the increased intracranial pressure and consequent stretching of the dura causing constant headache and sometimes intense suffering.

It is the duty of the surgeon in every mastoid operation, but particularly when operating upon a case where the symptoms have been of a severe or aggravated character, carefully to explore with a fine probe the roof of the antrum mastoideum and to investigate with minute care the cells bordering upon the sigmoid portion of the lateral sinus. Any fistulous track or suspicious cell in either region must be followed up with the curette, and every particle of pus, granulation tissue, or apparently unhealthy bone should be removed until the parts present the appearance of being perfectly healthy. Exposure of a healthy sinus wall or of a normal dura above, if done under proper aseptic precautions, is practically

* Med. News, 1888 and 1890; Am. Jour. Med. Sci., 1896.

without danger, and the best interest of the patient demands a thorough investigation of the field surrounding the diseased mastoidal cells. Every mastoidectomy is in some measure an exploratory operation, for no surgeon can safely predict beforehand the amount or extent of diseased tissue which he will uncover. Extensive extradural collections of pus may be found where least expected, and the successful mastoid surgeon is he who most thoroughly explores and cleans up his operative field.

Prognosis and Treatment.—The prognosis of extradural abscess is particularly good if an operation is performed before the disease has an opportunity to spread to or beyond the meninges. The very fact that a collection of pus has accumulated under the dura shows that nature is holding it in check, having built a wall around it, as it were, by adhesive binding of the neighboring dura to the bone; and, if nature be aided by providing an outlet for the pent-up pus, recovery is almost certain. Dench* reports 40 cases of extradural abscess, with only 4 deaths; of these, 1 died of pneumonia secondary to sinus thrombosis, 2 of general meningitis, and 1 of diabetes. It is worthy of note that 3 of these proved fatal because of extension of the abscess to the meninges or the sinus, and in but 1 was the extension post-operative.

The treatment, a detailed account of which appears on page 803, is necessarily surgical. As in the treatment of abscess elsewhere in the body, the quicker it is exposed and the cavity evacuated the sooner will a normal healthy condition be restored.

Intradural Abscess and Cortical Encephalitis.—A defined abscess between the dura and the brain must be a matter of very rare occurrence, and to diagnose its existence accurately is practically impossible. The few recorded instances have been discovered in the course of an operation for brain abscess or at autopsy examinations. In the same way a localized ulceration of the cerebral cortex is a rarity, though not to the same degree. A considerable number of cases of superficial encephalitis have now been observed, and, although the symptoms do not permit differentiation from brain abscess, the recognition of the lesion at the time of operation is important, inasmuch as the prognosis is better than that of purulent disease of the deeper structures of the brain. In none of the cases so far reported has incision of the diseased cortex revealed the presence of pus in the deeper parts, and the condition is not fatal. Voss† describes the appearance of the diseased area in one of his cases as having a bluish-gray color, with a sharp line of demarcation between it and the normal brain tissue.

Treatment consists in free exposure and drainage, if necessary, of the diseased area.

Cerebral Abscess.—Pathology.—In the majority of instances of brain abscess resulting from middle-ear disease it is the white matter of the temporo-sphenoidal lobe that is affected, and the pathway of the purulent process can be clearly traced through the roof of the tympanum or antrum. The gray cortical

* Trans. Sec. on Laryng. and Otol. A. M. A., 1906, p. 112.
† Med. Record, 1906, vol. lxix., p. 369.

substance of the brain, probably because of its higher vascularity, seems to be more resistant to infection than the underlying white matter, and a necrotic process may by erosion pass through the roof of the middle ear, establish a small extradural abscess or a localized pachymeningitis, bore a narrow channel through the meninges and the outer layers of the adjacent cerebral substance into the white matter, and there—by reason of the greater ease with which this part of the brain tissue succumbs to the invading micro-organism—form a well-defined abscess. As the abscess grows by a breaking down of the white matter, the channel of invasion may remain in a quiescent state or close behind it, even becoming entirely obliterated. The newly formed tissue along this track of suppuration from the tegmen to the abscess has been called the stalk of the abscess and may be cord-like in appearance or have a patent lumen.

This method of direct extension of the purulent disease from the middle ear to the brain substance is the pathological process most commonly found, and the experience of most observers appears to bear out Koerner's statement that the mass of brain substance which separates the abscess cavity from the point of union between the dura and bone is, as a rule, only a few millimetres broad and almost always diseased.

In the indirect method of formation a brain abscess may result through the metastasis of the infection from the tympanum or mastoid to some portion of the cerebrum, the intervening bones and meningeal tissues remaining perfectly healthy. This can be accomplished through the medium of the smaller blood-vessels. For instance, an arteriole may convey infective material and deposit it, in the form of an embolus, at one of its terminals, thus providing a focus from which an abscess develops; or a vein traversing the region becomes infected and there follows a thrombo-phlebitis, which terminates in local necrosis and abscess formation. Perhaps, more frequently, the perivascular and perineural sheaths are the routes by which the infective agent travels from the region of the middle ear to the brain.

Brain abscesses vary greatly in size. Knapp* has reported one which measured as much as 6 by 8 cm. They may be multiple in number, and oftentimes no connection can be discovered, either by the naked eye or microscopically, between the several abscess cavities. In the acute cases of short duration the abscess has no limiting membrane, but in the chronic, long-standing cases a distinct capsule generally forms, sometimes of considerable thickness. Even a dense investing membrane does not necessarily hinder the growth of the abscess. The capsule is formed by granulation tissue thrown out from the surrounding healthy structure; for Nature endeavors in this manner to wall off the advancing disease. This effort to produce a capsule may be repeatedly renewed as the abscess erodes the inner surface. An encapsulated abscess may cease to extend, and may remain latent for an indefinite period of time. The capsule may vary in thickness from 1 to 5 mm., and the shape of the sac is irregular, being occasionally round, but more frequently ovoid. The inner surface of the capsule is smooth and covered by a layer of degenerated fat cells,

* Archives of Otology, vol. xxiv., p. 121.

which gives it an opaque yellowish-white appearance. The external layer of the capsule is composed of newly formed fibrous tissue, and between this and the innermost, smooth layer is a loose spindle-celled connective tissue infiltrated with numerous small round cells. Surrounding the sac there is usually a zone of fatty degeneration; and extending beyond this, oftentimes for some distance, the brain tissue is softened and œdematous. The contents of the sac consist of pus with flakes or shreds of broken-down brain tissue and decomposed blood. In consistency it may be thin and watery or so thick that it can scarcely flow through the ordinary cannula. In many cases it has been described as green or yellowish-green in color and of an extremely fetid odor. When hemorrhage has occurred into the abscess, the decomposing hæmoglobin imparts a brownish color to the pus.

Diagnosis.—The diagnosis of otitic brain abscess, which is nearly always difficult, is, in uncomplicated cases, based upon the history of an acute or chronic suppurative otitis media and the gradually increasing evidences of cerebral disturbance. Those evidences which are particularly characteristic are: severe headache, drowsiness or sluggish cerebration, and projectile vomiting, associated with moderate fever and slow pulse. Owing to the great importance of an early recognition of the disease, numerous attempts have been made to classify the symptoms and to divide the clinical history of the affection into stages. Thus, in the first, or initial, stage are grouped those symptoms which relate to cerebral irritation in general; in the second stage are placed both the general and the focal symptoms of intracranial pressure; and to the third, or terminal, stage belong the manifestations of cerebral pressure, plus constitutional toxæmia. Naturally, such divisions cannot be sharply defined, because so many of the possible symptoms may be entirely absent in many cases, and, when present, those of the different artificially arranged stages may overlap.

First Stage.—The early indications of cerebral abscess are, in the order of their relative diagnostic importance, as follows:—

(*a*) Pain and Tenderness.—The headache may be diffused over the entire head or localized in the temporal region; occasionally it is referred to the frontal region. It is of a severe nature, but in that respect does not differ from the headache of meningitis or of extradural abscess. Very often tenderness may be elicited on percussion over a defined area,—over that, namely, which proves, later, to have been the site of the abscess. As the majority of such abscesses are in the temporo-sphenoidal lobe, and not far from the surface, this area of tenderness is apt to be found about an inch above and slightly posterior to the external auditory meatus.

(*b*) Temperature and Pulse.—The pulse-rate is abnormally low in brain abscess, varying, in uncomplicated cases, from 45 to 70; it may fall even below 35 per minute, and hold on between 40 and 50 for days at a time. The temperature is likewise of a lower degree than in other intracranial inflammations, frequently dropping to a subnormal point and rarely rising much above 100° F. unless associated with meningitis. The occurrence of a subnormal temperature in the evenings is especially significant of brain abscess.

(*c*) Vomiting.—One of the most constant symptoms of brain abscess is vomiting. It may be present in the initial stage or may not come on until other pressure symptoms develop. It possesses a rather typical character and differs from the vomiting induced by gastric disturbance in that it is not preceded by nausea, and also because the vomitus is ejected forcibly and without warning. The attacks are often precipitated by the slightest change of the patient's position.

(*d*) Blood Examination.—The leucocytosis is higher than that accompanying sinus thrombosis, and, in some cases, as high as that of leptomeningitis. The relative percentage of polymorphonuclear cells is, in like manner, excessive, being in some instances as much as ninety-five. A high grade of leucocytosis and, especially, a high percentage count of polymorphonuclear cells, are noted particularly in the early stage of brain abscess, before a limiting membrane has had time to form, and indicates Nature's effort to combat the absorption of pyogenic material by the delicate brain substance. In the chronic cases with a firm capsule there is not the same opportunity for absorption, and hence the leucocyte changes are not so great.

Second Stage.—Here we have, in addition to the symptoms already enumerated as appearing in the initial division, what may be considered as evidences of increased intracranial pressure. The symptoms of the first stage are all exaggerated; the headache becomes more constant, the pain is sometimes excruciating, and the local tenderness on percussion becomes greater; vomiting is repeated more frequently; the pulse and temperature remain low. Anorexia and constipation are prominent symptoms in some cases. Dizziness is frequently complained of, and its appearance is difficult of explanation. One would expect it to be rather indicative of cerebellar disease, yet it appears in quite as large a percentage of cerebral as of cerebellar abscesses. A slow, sluggish cerebration is an important sign. The patient does not respond promptly to a question, but, after a considerable period of delay, sometimes so long as to make the inquirer think that the question was not heard or has been forgotten, he answers with slow and deliberate speech, but with perfect intelligence. Convulsions are common in young patients, and a mildly comatose or stupid condition may be evident in this stage. Optic neuritis is always an important sign of intracranial pressure and should be watched for with care in order that the earliest evidence of its beginning may be detected. An examination of the eyes for abnormal pupillary action may be very helpful. So long as the pupils respond equally and quickly to light and accommodation, excessive brain pressure may be ruled out. Irregularity of action and slow response to light point strongly to irritation of the brain. Absolute loss of reaction to both light and accommodation indicates a high degree of disturbance and suggests a grave prognosis. Impairment of action, rather than the amount of contraction or dilatation, is the point to be considered.

In some instances focal symptoms, dependent upon involvement of a definite part of the brain, are apparent. Since cerebral abscess resulting from middle-ear disease is generally found in the temporo-sphenoidal lobe and more frequently on the right than the left side, localizing symptoms will not be ascertainable in the majority of cases. The right temporal lobe represents one of the "silent" areas of the brain, and abscesses limited to this lobe give rise to only general symptoms. The characteristic disturbances from involvement of the left temporal lobe are word-deafness and defective speech. The most commonly observed types of aphasia are: sensory aphasia—inability to understand the meaning of written or spoken words; amnesic aphasia—inability to remember words; and paraphasia, where the patient miscalls objects and substitutes wrong words. Efforts at exact localization from these alterations in the function of hearing and expression have not yet been productive of very great practical results. Cushing states that a single pathognomonic symptom follows a destructive lesion of the superior temporal gyrus on the left side—namely, word-deafness or inability to apprehend spoken language.

Third Stage.—The terminal period of cerebral abscess is marked by increased gravity of all the preceding symptoms. Its approach may be gradual or sudden. Restlessness and great irritability, or deep coma, high temperature and rapid pulse, possibly chills and repeated shivering, and choked disc show the septic intoxication and extreme cerebral pressure. Cheyne-Stokes respiration and profound coma usually mark the end, but death may be sudden from rupture of the abscess into the lateral ventricle, causing a stoppage of the heart and respiration.

Since successful treatment of a cerebral abscess depends upon evacuation of the abscess cavity in time to prevent the serious complications just mentioned, it is apparent that the diagnosis must be made during the initial or early part of the second stage, and treatment instituted immediately. The conditions are not absolutely hopeless later on, and the patient should be given the benefit of operative intervention, but the mortality in delayed operations will necessarily be high. In cases of chronic middle-ear suppuration or of mastoiditis with symptoms suggestive of cerebral invasion, it is far better to perform a mastoidectomy and explore the brain through its base very early than to await the appearance of positive symptoms, only to go in too late.

Cerebellar Abscess.—PATHOLOGY.—The explanation of the formation of a cerebellar abscess is the same as that of the cerebral, except that the course of invasion is through the posterior mastoidal cells or the postero-superior surface of the petrous portion of the temporal bone, after traversing the labyrinth. Just as, in the cerebral cases, we have observed the eruption of the extradural abscess, perforation of the neighboring dura, and destruction of the brain substance, so, in the building of a cerebellar abscess by the direct method, the process can usually be traced through the mastoid antrum and cells to the formation of an extradural (called here a perisinous) collection of pus over the sigmoid portion of the lateral sinus and the attack upon the cerebellar substance.

SYMPTOMATOLOGY.—All of the general symptoms of brain abscess given above apply equally as well to the cerebellar as to the cerebral form of the disease. From a study of these it can only be said that the patient probably has a brain abscess; the diagnosis between cerebral and cerebellar depends upon the differing localizing signs or upon the course taken by the disease as it advances inward from the ear,—a course which is exposed to view in the progress of the operation. Tenderness over the occiput, instead of over the temporal region, naturally leads one to suspect a focus in the cerebellum. Torticollis, vertigo, nystagmus, muscular weakness and especially muscular inco-ordination, point suggestively to the cerebellum as the site of the disease. The vertigo in cerebellar disease is often associated with an apparent motion of the surrounding objects, which seem to move from the side of the lesion toward the healthy side. If a patient with cerebellar abscess attempts to walk there is apt to be a staggering gait or an inclination to walk to the right or left from a straight line—symptoms which are better observed if the patient be requested to keep his eyes closed during the test. The nystagmus is made evident, or increased, when the patient directs the visual axes strongly toward the affected side, and attempts to maintain the eyes in that position for a time.

Prognosis.—The prognosis of brain abscess is favorable only in those cases which are recognized early and promptly treated. Spontaneous recovery by discharge through the original channel of infection and the external auditory canal has been known to take place, but such a desirable outcome cannot be anticipated. Even the chronic, latent cases are a source of imminent danger, sudden death occurring from rupture into the fourth ventricle, for instance, and from pressure upon the vital centres. Surgical intervention offers the only hope of preserving life and should be supplied at the earliest possible moment. Under such treatment the prognosis has steadily improved in recent years. Aseptic measures having made it safe to enter the cranial cavity, many more cases are now submitted to early operation than was formerly the custom.

Dench* has collected from the literature 100 cases of cerebral and 102 cases of cerebellar abscess, for the purpose of studying the symptoms, operative procedures, etc. Of the cerebral abscesses he says, regarding the prognosis: "The results of operation show 52 cures and 48 deaths. It is interesting to note the method of operation in these cases. In 41 cases the abscess was opened through the tegmen, and, of these, 27 were cured and 14 died. Thirty-seven cases were opened through the squama, and, of these, 18 were cured and 19 died. In 22 cases the method of operation is not mentioned; of these 7 were cured and 15 died."

Concerning the same points in the treatment of cerebellar abscess he says: "Out of 102 cases collated, in 45 the abscess was opened behind the lateral sinus, and, of these, 25 were cured and 20 died. In 11 cases the abscess was opened in front of the lateral sinus, and, of this number of cases, 4 were cured and 7 died. In 46 cases the method of operation was not stated, and, of these, 4 were cured and 42 died."

In another article † Dench gives his personal experience with 14 cases of brain abscess. Ten were located in the temporo-sphenoidal lobe, and, of these, 4 were cured and 6 died. The other 4 were located in the cerebellum, and all terminated fatally.

Starr ‡ says of the prognosis in brain abscess: "I have been over the litera-

* Trans. Amer. Otol. Soc., 1907, p. 486.

† Trans. Sec. Laryng. and Otol. A. M. A., 1906, p. 112. ‡ Med. Record, 1906, vol. lxix., p. 369.

ture from 1900 to 1906 and have been able to collect 54 cases of temporal, 25 cerebellar and 2 occipital abscesses, in all 81 cases of brain abscess, secondary to otitis, in which an operation had been performed. In 6 of these nothing was found at the operation, but the abscess was discovered at autopsy. In 42 cases recovery followed operation; in 39 cases death occurred. The cerebellar cases were particularly unfavorable, for, of the 25 cases, 16 died." In speaking of the still too high mortality of otitic brain abscess, Starr calls attention to the postponement of most of these operations to too late a date.

Treatment.—As regards treatment, an abscess of the brain should be dealt with on exactly the same principles as an abscess elsewhere in the body, viz., by incision and free drainage. The accumulated experience of many operators shows very clearly that, in the vast majority of instances, the middle-ear suppuration, when it invades the brain, follows certain definite pathways; that, as a general rule, cerebral abscesses are located in the temporo-sphenoidal lobe; that in such cases the route of infection is most apt to be through the roof of the tympanum or antrum, the abscess lying not far from the diseased bone and being connected therewith by a necrotic channel or "abscess stalk"; that cerebellar abscesses are usually found in the vicinity of the lateral sinus or near the openings of the internal auditory meatus or the aquæductus vestibuli or the cochlea. Consideration of these several points indicates very distinctly that the operative treatment should consist in an attack upon the middle-ear disease, obliteration of all evidences of purulency in the tympanic cavity and mastoid process, and a careful examination for fistulous tracks leading into the cerebral or cerebellar cavities. When once such an infective pathway has been found, it is an easy matter to follow it to the abscess cavity and supply drainage. Failure to trace a connection between the aural disease and a suspected brain abscess necessitates an exploration through the squamous portion of the temporal bone above the middle ear, or through the occipital bone posteriorly to the lateral sinus.

By attempting to follow, surgically, the same course as that pursued by the disease, several important advantages are gained. In the first place, a complete mastoid operation must be performed in any event and should come first, unless the patient is in a precarious condition from high intracranial pressure, because it may furnish positive evidence of the site and nature of the brain complication. Secondly, the mastoidectomy may obviate the necessity for opening the intradural cavity. Thirdly, if the abscess be thus discovered it is more satisfactorily drained through the original channel of infection, and with less danger, because it does not have to drain over healthy meninges.

As an illustration of the second point, as well as showing the difficulty in making a positive preoperative diagnosis, I may here relate an interesting and hitherto unpublished case:—

E. H., aged nine years, was first seen by me on March 20th, 1907, in consultation with Dr. Frank R. Smith. The patient was convalescing from an attack of measles, throughout which she had suffered more or less earache, but the physician had not been called until the morning of this date and then because she had suffered severe general headache during the previous night, followed by repeated spells of vomiting. Dr. Smith recognized the aural condition, and when I saw her at 3:30 P.M. the right tympanic membrane was bulging and yellowish in color. Temperature 102° F. Paracentesis was immediately performed. At that time there was apparently but slight tenderness over the mastoid antrum. At 9 P.M. Dr. Smith called me to say that the child was reported to be having convulsions and was in a serious condition. She had two convulsions before he saw her and was beginning the fifth while we watched her together. This was the first one that presented any characteristic appearances, but it was typically Jacksonian of the left side. From that time until midnight one convulsion followed another in rapid succession, always of the Jacksonian type. The child was unconscious all the time and the pulse and respiration gave a hopeless aspect to the situation. Early in the morning the convulsions ceased, and when I saw her again at 9 A.M., March 21st, she was conscious. She complained constantly of intense, diffuse headache, and the entire right side of the head was sore to the touch and there was marked tenderness over the entire mastoid region. Operation was performed at 1:30 P.M. The antrum was found to be filled with granulation tissue, and, when this cavity had been cleansed, pus could be seen dripping into it from above. The tegmen antri was found to be carious and was removed, as was also considerable carious bone in an outward and posterior direction along the floor of the cranium. The extradural abscess thus revealed was evacuated of about one drachm of pus, leaving exposed an area of diseased dura about 2 cm. in diameter. The abscess cavity had been apparently completely walled off. The sinus was exposed and found to be healthy. The child made a perfect recovery, without at any time having a complicating symptom.

Here was a case in which there seemed to be a lesion definitely localized in the motor zone of the cerebrum, yet, by following the diseased tract from the middle ear, we were saved the embarrassment of a futile operation upon the brain, which would have revealed the fact that the lesion was located at a point remote from the suspected area.

IV. SURGICAL PROCEDURES.

The general preparation of patients for operations upon the head are the same as those preceding any major operation, provided there is time to permit looking after the diet, administering an enema, etc.; but many of the serious brain cases are so ill as to demand immediate operative attention, and under such circumstances the preliminary work consists mainly in aseptic preparation of the surgical field. Whenever it is possible, the head should be prepared the night before, or at least some hours before, the proposed operation. The entire head should be closely shaved and the scalp carefully cleansed by many scrubbings with soap and brush. After complete removal of the soap, by irrigation with sterile water, the scalp should be thoroughly rubbed over with gauze sponges soaked first in alcohol and afterward in ether, and then it should be washed with bichloride solution. The application of a sterile gauze cap or a sterile towel, soaked in bichloride, will protect the scalp until the time for operation. The scrubbing with soap and cleansing with alcohol and bichloride solution should be repeated just prior to beginning the operation.

The greatest possible care should be observed in the sterilization of all instruments and appliances that are to be brought near to, or in contact with, the patient. The rules that apply to abdominal surgery should be enforced with even a greater degree of strictness in the performance of cranial surgery. Objects that cannot be submitted to boiling can be safely treated in the formaldehyde sterilizer, and no person or object not assuredly sterile should be permitted to approach the patient. Sterile sheets and towels cover the patient completely and prevent the operator or assistant from touching anything that is not clean. The anæsthetist should be separated from the operation field by some tent-like arrangement of sterile sheets which obviates any possibility of his touching the clean surroundings or being touched by the other workers. Each of the assistants, as well as the operator, must follow the most rigid technique in the preparation of the hands and in the donning of his operating-costume. All should observe watch-

FIG. 395.—Simple Mastoidectomy. (Original.) The outer cortex and cellular structure of the mastoid process have been completely removed, the antrum opened, and the bony wall of the sigmoid portion of the lateral sinus outlined from the knee to its inferior curve under the mastoid tip.

fulness throughout the operation to prevent any break in technique. The sterile operating-suit or gown should be augmented by the wearing of sterile rubber gloves and a sterile mask for the face. The thin rubber gloves do not to a perceptible degree impair the sense of touch, and the fact that they can be boiled affords a greater assurance of sterilization than one can possibly feel after any treatment of the hands. A nurse, or special assistant, personally prepared with the same painstaking care observed by the operator, should be in readiness to receive instruments that have been once used and to cleanse them in some antiseptic solution preparatory to the surgeon's requiring them a second time.

It seems almost superfluous in this day to enumerate the details of aseptic technique in the operating-room and to insist upon the necessity for a strict observance of the recognized laws of aseptic surgery; yet I am convinced that we are more in need to-day of a rigorous enforcement of the principles of asepsis than of the discovery of new surgical measures.

When the patient is placed on the operating-table some care should be exercised to secure a comfortable position, with the head and shoulders slightly elevated. Intracranial pressure is thus diminished and engorgement of the venous sinuses reduced to the minimum, so that hemorrhage or oozing from the bone and small vessels is prevented or more easily controlled. In the choice of an anæsthetic, unless there be some sufficient reason for avoiding it, chloroform should be employed in brain operations. Safety in its use is enhanced if it can be administered by one of the modern methods whereby a vapor of two per cent or less of chloroform may be given as required.

Mastoidectomy.—Suppurative otitis media being the cause of the pyogenic diseases of the brain here under consideration, and it being possible to reach

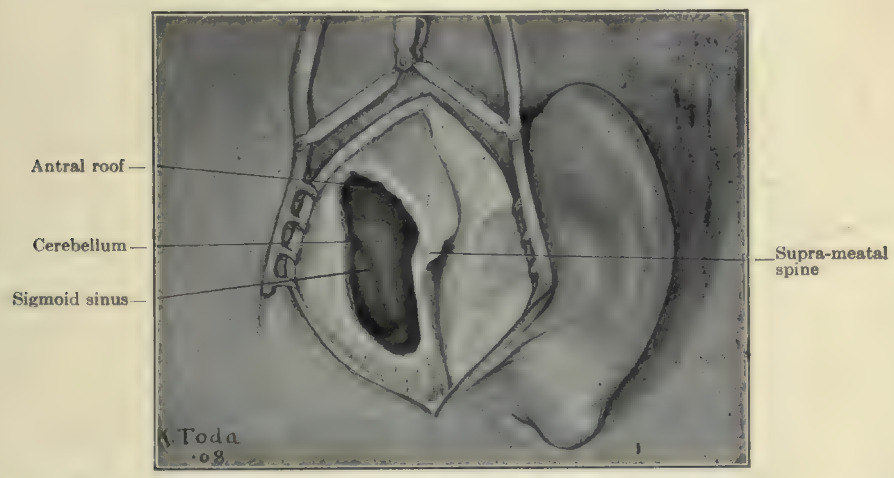

Fig. 396.—Extension of Mastoid Operation by Removal of Bony Covering of Sinus, to expose that vessel and the cerebellar dura in front of it. Performed for evacuation of perisinous extradural abscess, extraction of a thrombus from the sinus, or exploration of the cerebellum anteriorly. (Original.)

almost any part of the brain usually affected in this way from the mastoid wound, the operation of mastoidectomy constitutes the first part of surgical treatment of these affections unless there be some urgent reason for more directly and immediately entering the cranial cavity. This part of the subject, however, is fully discussed in an earlier article in the present volume, and I may therefore pass at once to the consideration of the proper manner of exploring intracranial abscesses.

Exploring an Extradural or a Cerebral Abscess.—Since the majority of extradural abscesses are situated directly over the mastoid antrum or tympanic cavity, or along the sigmoid sinus, and since nearly all otitic cerebral abscesses are located in the temporo-sphenoidal lobes, their exploration can be most easily and safely attained by a simple extension of either of the mastoid operations described elsewhere. (Page 693 *et seq.*) With the chisel, gouge, or burr the thin bony plate constituting the roof of the antrum can readily be perforated and the dura exposed. By the aid of bone forceps this opening into the cranial cavity can be rapidly extended in any direction until an ample area of the base of the brain is open to inspection. An extradural abscess can thus be satisfactorily drained through the mastoid wound, or, if leptomeningitis or brain abscess be suspected, the dura may be incised and a narrow-bladed bistoury or exploring needle introduced into the brain substance. Unless a track has been found leading from

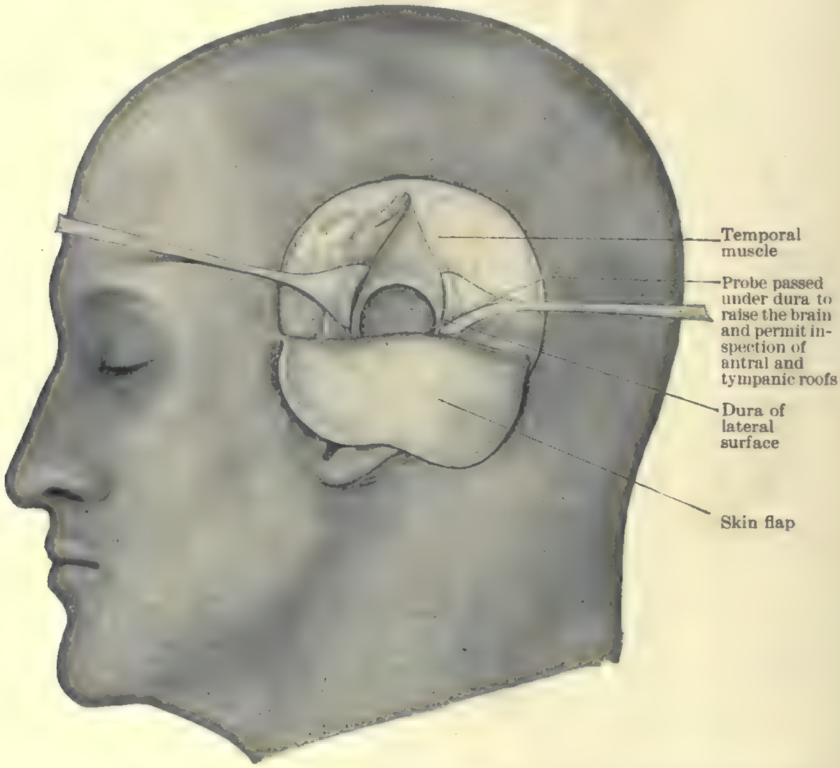

Fig. 397.—Exploration Field for Temporo-sphenoidal Abscess. After the intermuscular method of Cushing. (Original.) The flap of skin and fascia is turned down, exposing the temporal muscle, the fibre bundles of which are then separated in a nearly vertical line and a one-inch trephine opening made, the trephine pin being placed one inch above the suprameatal spine. With the aid of rongeur forceps the opening can be rapidly increased in size and the brain exposed to any desired extent.

the necrosed area through the dura, it is perhaps better to make a direct exploration for temporo-sphenoidal abscess, or to attempt drainage of a leptomeningitis, through an opening in the squamous portion of the temporal bone. To accomplish this, the incision in the soft parts may be extended directly upward and a trephine opening made in the temporal bone above, or above and posteriorly to, the external auditory meatus.

When one explores for brain abscess without a preliminary mastoidectomy, it is possible to take advantage of the operation suggested by Cushing,* for exploration and decompression in brain-tumor cases. (Fig. 397.) In this method

* Keen's "System of Surgery," vol. iii.

a skin flap is formed by a curved incision beginning in front of the auricle, just within the hair line, and extending upward, backward, and downward to the posterior border of the mastoid process. The fibres of the temporal muscle are separated in a vertical line, and the bone beneath is exposed by the aid of retrac-

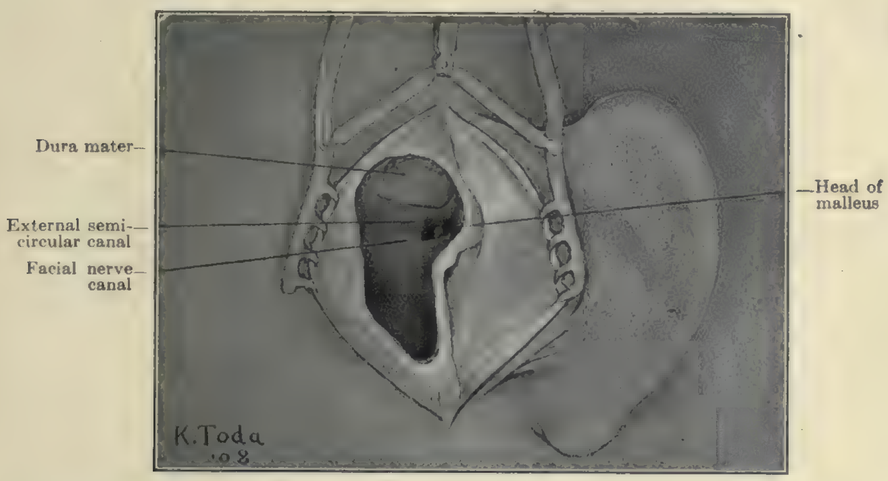

FIG. 398.—The Simple Mastoidectomy, extended by removal of the antral roof so as to expose the dura covering the base of the temporo-sphenoidal lobe of the brain. (Original.)

The intracranial field can be further enlarged by removal of the bone anteriorly (cutting out tegmen tympani), posteriorly or externally, with bone forceps. The operation is performed for the evacuation of an extradural abscess or for the exploration of the temporo-sphenoidal lobe for suspected cerebral abscess secondary to acute mastoid or tympanic disease.

Further explanatory details are given along the margins of the cut.

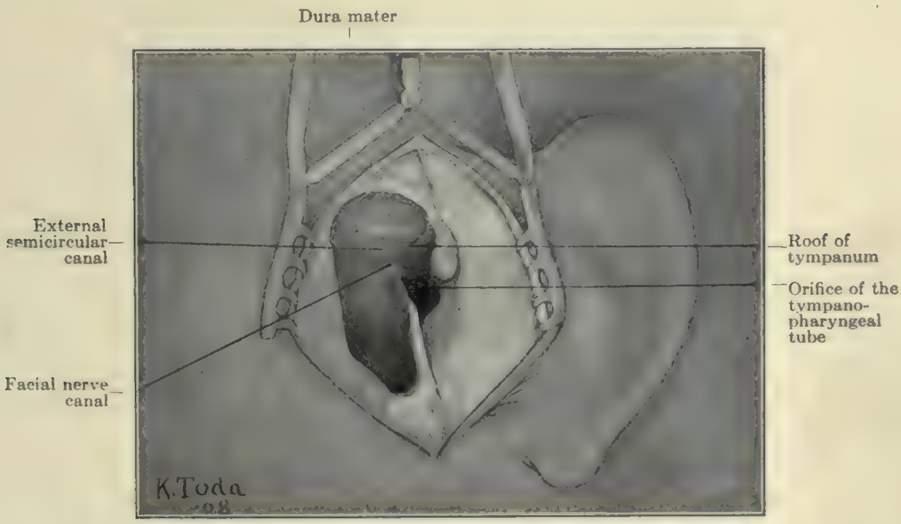

FIG. 399.—Mastoido-tympanal Exenteration—the so-called "Radical Mastoid Operation"—with removal of the antral roof for cerebral exploration. (Original.)

The operation is usually employed in cases of suspected intracranial disease secondary to chronic purulent otitis media. The mastoidectomy has been extended by removing the postero-superior portion of the wall of the external auditory canal and by extraction of the malleus and incus.

Further explanatory details are given along the margins of the illustration.

tors. A trephine opening is then made in the squama, one inch in diameter, the centre pin being placed one inch above the suprameatal spine. An opening in this region affords the easiest access to that part of the cranial floor which is directly over the tympanum and antrum. In cases where aphasic symptoms are present, and it is thought desirable to expose the posterior part of the superior and middle temporal convolutions, the trephine opening should be made with its centre at a point an inch and a quarter above and an inch and a quarter behind the external auditory canal. Either of these openings in the bone can be en-

Fig. 633.—Trephine Opening in Squamous Portion of Temporal Bone, to be employed when it seems undesirable to explore the brain from mastoid cavity. Original mastoid incision has been prolonged upward and temporal muscle split and retracted. Probe passing between dura and bony temporal ridge, from mastoid to temporal openings. (Original.)

larged to any extent desired by the aid of bone forceps. Bleeding from the cut edges of the bone can be readily controlled by the use of Horsley's wax and other means. (See page 344.)

To expose the brain, a dural flap should be cut, the flap to be lifted upward; and this can best be done by first lifting the dura carefully with a sharp hook, nicking it with the knife, and completing the line of incision with blunt-pointed scissors.

The best instrument for exploring the brain substance for an abscess is a narrow-bladed sharp knife. If pus be found, a grooved director may be inserted beside the knife-blade and maintained in position until the opening can be enlarged sufficiently to drain the abscess cavity and permit the introduction of dressings. Inspection of the abscess cavity and the application of after-dressings are facilitated by the use of Whiting's encephaloscope. (Fig. 343, No. 19.) The best form of drain for the abscess cavity is a "cigarette drain," composed of sterile gauze wick encased in a single layer of rubber tissue. After evacuation of the abscess and the introduction of a drain, the wound in the soft parts may be partially closed, an opening being left which is sufficiently large to permit free drainage and easy access to the abscess cavity. Irrigation of the abscess cavity is not generally advisable. When it is required, warm normal salt solution or a bichloride solution in a strength of 1 : 10,000 may be employed.

If internal serous meningitis demands tapping of the lateral ventricle in addition to lumbar puncture, for the removal of cerebro-spinal fluid, the point

Fig. 461.—Trephine Opening Below the Horizontal and Behind the Sigmoid Portions of the Lateral Sinus. Employed in exploring for cerebellar abscess. The primary mastoid incision bisected at its centre for a horizontal incision to extend posteriorly. (Original.)

of approach is through the middle temporal convolution, the director or needle being passed inward to a depth of about two inches if the ventricle is not entered, as it may be, if much distended, at a lesser distance.

Exploring the Lateral Sinus and a Cerebellar Abscess.—Exploration of the cerebellar region can be very readily made from the cavity created by the mastoid operation. An opening in the bony covering of the sigmoid portion of the lateral sinus, through the posterior wall of the mastoid cavity, is easily made by the chisel or gouge, and the entire sinus wall can then be readily removed, upward to the knee of the vessel, or downward to the jugular bulb, by the aid of bone forceps. The vessel itself is thus laid open to inspection and, if thrombosed, may be opened by a vertical incision, precaution having first been taken to control possible hemorrhage by the pressure of pledgets of gauze on the vessel wall above and below the proposed point of incision.

Abscesses in the cerebellum may be approached in front of the sinus by removing the inner wall of the mastoid cavity in front of and along the course of the sinus. The bone tissue is easily removed with the bone forceps, and the sharp-pointed bistoury or the exploring needle may be inserted into the exposed

Fig. 402.—Diagram Showing the Relationship between the Temporo-sphenoidal Lobe of the Brain and the External Landmarks on the Skull. (Modified from Kroenlein.) Dotted lines mark the sutural junctions of the cranial bones. Reid's base line (*A* to *B*), drawn horizontally backward, from the inferior margin of the orbit through the external auditory meatus, indicates the floor of the cerebral cavity. The superior horizontal line (*C* to *D*), drawn posteriorly from the supraorbital margin, parallel with the base line, approximately marks the upper boundary of the temporo-sphenoidal lobe. The positions of the Sylvian and Rolandic fissures are indicated by the radiating lines (to *E* and *F*) and the course of the sigmoid sinus is outlined by faint solid lines over the mastoid region.

cerebellum. To reach the cerebellum from a point situated posteriorly to the sinus, an incision, beginning at the centre of the original mastoid incision and extending horizontally backward a distance of 5 or 6 cm., is made in the soft parts. A trephine opening in the exposed bone, so situated that the trephine rests anteriorly at the posterior edge of the mastoid process and, superiorly, just below Reid's base line (Fig. 402), will expose the dural covering of the cerebellum behind the sigmoid and below the horizontal portion of the lateral sinus.

Historical Note.—Brain surgery is, comparatively speaking, too young a branch of the general art to have yet had its history written. The ancients, it is true, were by no means ignorant of brain diseases and of certain methods by which they might be treated. Nevertheless, their knowledge was very scanty. Indeed, more progress has been made in the recognition and surgical treatment of brain diseases during the past twenty-five years than in all the ages of time before. When a historical review of the whole subject shall have been prepared, it will surely be found that one of the most interesting chapters will be that setting forth the evolution of our knowledge of pyogenic affections of the brain. The credit for awakening the professional mind to the importance of these diseases, and the honor of having comprised in one masterpiece of writing all of the world's knowledge of the subject, together with the clear, concise, and sage counsel of a successful and experienced worker in the field, belong to Sir William Macewen, whose monograph on the "Pyogenic Diseases of the Brain and Spinal Cord" appeared in 1893. To him, more than to any other one person, we are indebted for the present advanced position in the treatment of the purulent intracranial affections. It is impossible here even to name all those who have contributed to our knowledge of the pathology, diagnosis, or successful treatment of pyogenic intracranial diseases of otitic origin, but it cannot be considered invidious to mention a few names of those to whom we are greatly indebted: Koerner, Kroenlein, and von Bergmann, in Germany; Sir Victor Horsley and C. A. Ballance, in England; and, among our own countrymen, Keen, Starr, Cushing, Holt, Dench, Whiting, Crockett, and McKernon. In the publications of these men we find a fair summary of the present situation and much excellent advice, based upon large experience.

SURGICAL DISEASES AND WOUNDS OF THE PHARYNX.

By CHARLES H. KNIGHT, M.D., New York City.

I. ANOMALIES AND MALFORMATIONS.

Deformities of the pharynx may be congenital or may result from disease or injury. Of the former the most common type is that familiar vice of development known as cleft palate. In its rudimentary state it is often seen as bifid uvula, a condition seldom productive of discomfort and not requiring correction. When the fissure invades the velum and even the hard palate, nutrition in early life is seriously impaired and, if the patient survives, the effect on the voice is marked. Operative measures should be undertaken before bad habits of speech have become confirmed and before the tissues at the margins of the cleft have become excessively thinned. In the latter case it is difficult to secure union, and the only alternative is the adjustment of an artificial palate.

Slits or perforations in the pillars of the fauces, especially the anterior, are sometimes seen. They cause no disturbance and are generally discovered by the general surgeon. Pouches and diverticula of the pharynx (pharyngocele) are occasionally met with, more often in the lower pharynx, and are usually of branchial origin. Those in the epipharynx are most rare and arise from the first cleft. Those from the tonsillar fossa are associated with the second, while pouches in the lower pharynx result from congenital defect in the third branchial cleft or simply from weakness in the muscular wall of the pharynx. It is possible to secure a very graphic demonstration of the dimensions of a pharyngocele by means of the Roentgen ray after the pouch has been filled with bismuth emulsion, which is impervious to the rays. Fistulæ and cysts are often associated with these conditions. The latter, when seated anteriorly in the region of the base of the tongue, may be found to originate in the thyro-glossal duct. They are best reached by an external operation, since their extirpation through the mouth is difficult and a partial removal is always tantamount to a failure. Successful closure of a patulous thyro-glossal duct or of a pharyngeal fistula is likewise dependent upon complete obliteration.

Dermoid cyst (teratoma) is a rare anomaly; it is generally found in the upper pharynx, attached to the basilar process of the occipital bone, and frequently it invades the cranial fossa. Examples of successful removal are on record, but in advanced degree the condition is beyond relief. Speech, deglutition, and respiration are impeded more or less according to the situation and dimensions of the tumor.

Distortions, adhesions, webs, and adventitious bands are met with in the pharynx as sequels of constitutional disease, especially syphilis, or of a more acute process such as diphtheria, scarlet fever, or typhoid.

Vascular anomalies, like a large pulsating vessel, on the posterior pharyngeal wall, or a misplaced ascending pharyngeal artery, angeiomata of the soft palate, etc., are of interest chiefly in connection with the use of cutting instruments in this region. Serious hemorrhage might follow a wound of such a vessel, and the wisdom of carefully inspecting the parts before they are subjected to the use of the knife, is therefore apparent.

Attention has been drawn to a peculiar prominence of the bodies of the cervical vertebræ in certain individuals, which in itself has no special significance, but might readily be mistaken for a more important pathological condition.

In the rhinoscopic mirror are sometimes observed bands of tissue running from one of the cushions at the entrance of the Eustachian tube to the lateral or posterior wall of the naso-pharynx. They are possible remnants of lymphoid hyperplasia or a result of erosions of the mucous membrane, and are suspected to bear some relation to subjective aural disturbances, tinnitus, etc.,—symptoms which are often present. Abnormal size of the Eustachian cushions has been observed to cause postnasal stenosis and symptoms simulating those of pharyngeal adenoids.

Various congenital deformities of the epiglottis have been described. It may be of abnormal thickness or of abnormal size in general, or may be, in the opinion of some authorities, so distorted as to impair deglutition. This view is based on the assumption that the function of this organ is to divert ingesta from the opening of the glottis toward the food track. Yet those in whom the epiglottis has been removed by disease or operation suffer no inconvenience in swallowing. If its action is that surmised, Nature has evidently provided an adjuvant or a substitute in the ventricular bands or other structures.

II. WOUNDS AND FOREIGN BODIES.

Injuries of the upper pharynx are comparatively rare. Those of the middle and lower pharynx result, in a large proportion of cases, from swallowing corrosive or irritating substances and are apt to be followed by distorting and contracting cicatrices which may be a source of danger to life as well as of discomfort. Burns and scalds from the use of excessively hot fluids, and especially from the contact of acids taken by accident or with suicidal intent, are often followed by intense reaction, and permanently serious damage may be inflicted upon the parts thus burned. In attempted self-destruction by cutting the throat the knife blade is often found to have entered the pharynx through the suprahyoid space, the epiglottis having been severed. These cases are difficult to handle and must be treated according to individual indications. In gunshot wounds the mutilation of neighboring structures usually overshadows that of the pharynx. The propensity of children to carry objects protruding from the mouth involves great risk. Serious laceration of the velum and pharyngeal wall and invasion of the spinal canal or the base of the cranium may be caused by a fall or blow against a long sharp-pointed object thus held.

Foreign bodies in great variety are met with in the air tract. A large proportion of those detained in the oro-pharynx are small and sharp, like fishbones, pins, and similar objects. The follicles of the tonsil, the lymphoid tissue at the base of the tongue, and the pyriform sinus are favorite points of lodgment. Careful search should be first made with the mirror and a strong light, and in some cases under cocaine, before exploration is made with the finger. Incautious use of the latter may drive an embedded foreign body still deeper into the tissues and thus increase the difficulties of extraction. These cases call for the exercise of the utmost tact and patience, since nervousness and fright aggravate the local irritability excited by the foreign body. The resemblance, in the mirror, of a shred of viscid mucus to a fishbone is often noticeable, but the two objects are differentiated by the use of the cotton-wound end of a probe. When the foreign body has been located, its removal with forceps and with the aid of cocaine is seldom difficult. A large mass, like a bolus of food or a piece of meat, may be so fixed at the rim of the glottis as to cut off the air supply and destroy life unless it be promptly removed or the windpipe opened without delay. On the other hand, in several instances a body of considerable size, like the plate for an artificial tooth, has been known to be held in the pharynx several weeks, the symptoms which it caused having meanwhile been wrongly interpreted.

In a large number of cases the foreign body has passed on, having torn or irritated the mucous membrane at some point and having left behind the sensation of still being present—an illusion of which it is almost impossible to disabuse the mind of the patient. Imaginary foreign bodies constitute a large percentage of these cases. In nervous or hysterical subjects insistence on the presence of a foreign body is a frequent phenomenon, even when there is no history or knowledge of one having been inhaled or swallowed. When a foreign body has reached the laryngo-pharynx, it becomes of interest from the possibility of its penetrating the wall of the larynx or becoming so impacted at the narrowest part of the gullet, opposite the cricoid cartilage, that its removal is feasible only by external pharyngotomy. (See article in Vol. VI. on Surgery of the Neck.) In these cases the pharyngoscope may sometimes be used with advantage. A foreign body out of sight in the laryngo-pharynx or buried in the mucous membrane may be located by means of the x-ray. The naso-pharynx is but seldom invaded by a foreign body. One may slip into or be pushed back to the cavity of the pharynx from the nasal fossa, and the contents of the stomach are sometimes ejected up into this region, particularly in coma from alcohol or from other cause or during the unconsciousness resulting from the administration of a general anæsthetic. The accident is also favored by paralysis of the velum after diphtheria or from a lesion of the central nervous system. Parasites likewise may find their way thither from the stomach. The case recorded by Heath of a gun-breech which was lodged for twenty-one years in the antrum, and finally was extruded by way of the pharynx, is without parallel. There are two dangers from prolonged retention of a foreign body: one is the occurrence of excessive swelling and œdema at a point where life might be menaced by impediment to respiration; and the other is the formation of a phlegmon in the wall of the pharynx. The latter may not only obstruct breathing and swallowing, but may induce septic infection. Under these circumstances an external operation is preferable; otherwise it is best to do a preliminary tracheotomy and endeavor to reach the affected part through the mouth. Fortunately, the majority of these patients seek relief promptly, or, if they do not, it is because the foreign body excites but little irritation and at length is spontaneously expelled without having caused much disturbance. On the other hand, if the object is sharp and thin like a needle, it may make its appearance years later at some remote point in the body.

III. PHARYNGITIS; AMYGDALITIS.

Pharyngitis.—Etiology and Symptoms.—The so-called "cold in the head" often begins with a feeling of dryness and discomfort referred to the region of the pharynx above the soft palate; in other words, as an acute or a subacute rhino-pharyngitis. This is explained by the fact that irritants and infections in the air are carried by the inspiratory current directly to this surface. The course of an inflammatory process here is like that of mucous membranes in general. First, there is a period of dryness and congestion, which lasts for only a short time. Then follows a stage of mucous effusion, which ultimately subsides or gives place to a condition popularly known as "chronic catarrh." The latter is characterized by the accumulation, in the postnasal space, of viscid secretion which the patient makes violent and often ineffectual efforts to dislodge by blowing the nose and by the unpleasant practice of "hawking." The secretion, if not ejected, is swallowed and receives the blame for various derangements of digestion. To some it seems quite as proper to charge the stomach with responsibility for the air-tract disorder. At any rate, we often find the two associated, and in every case of chronic catarrhal trouble in the upper air-tract it is equally important to regulate the gastric function and to correct intranasal abnormalities. Without proper attention to the latter, especially, treatment of the catarrhal process is utterly hopeless. It is very common to hear the saying that "It is impossible to cure catarrh in this climate." Probably this conclusion is a result of failure to recognize these factors in the etiology of catarrhal disease. Nasal stenosis dependent upon the presence of a septal deviation or spur, or a hyperplastic turbinate, or upon some other cause must be remedied before any lasting effect from local treatment of the pharynx can be expected.

Treatment.—For local applications almost all the remedies in the list of astringents have been tried. The most popular is silver nitrate in various strengths. Its primary effect is so disagreeable that a search has been made for a less irritating silver salt. Perhaps the most satisfactory is silver vitellin (argyrol), against which no objections are raised where it is employed in solutions having a strength of from ten to fifty per cent. It does not coagulate secretions and possesses great penetrating power with no tendency to set up a violent reaction.

The most satisfactory routine treatment in these cases is: first, to cleanse the parts with normal salt solution; next, to apply argyrol with a cotton pledget on a postnasal applicator; and, last, to follow this application with a spraying of the anterior nares with mentholized albolene (gr. ii.–v. to ℥ i.). If the secretions are very tenacious, the preliminary cleansing may have to be done with a nasal douche or a postnasal syringe. In certain cases a different astringent —*e.g.*, silver nitrate, zinc chloride, iron perchloride, or glycerite of tannin—may be found more effective; and, then again, certain individuals dislike the oil spray, which may then be replaced by an alkaline watery solution.

Complications.—As an occasional complication is observed sinus disease, especially empyema of the posterior ethmoid cells or of the sphenoid sinus, which must be first relieved. A rare and interesting source of confusion is met with in the form of inflammation or cyst of the pharyngeal bursa (Tornwaldt's disease). The symptoms of the latter closely resemble those of adenoids, but the condition is practically restricted to adult life and in the rhinoscopic mirror may be differentiated without difficulty. Some of the few cases on record seem to have been rather intractable, while others were cured by use of the curette and the electric cautery. On posterior rhinoscopy the nasopharynx is seen to be more or less filled with a peculiar glairy viscid mucus, the source of which is an antero-posterior median cleft in the vault of the pharynx —the entrance to the *bursa pharyngis*. Occlusion of this cleft leads to accumulation of secretion in the bursa and consequent cystic formation with more or less tumefaction.

In some cases of pharyngitis the force of the morbid process is expended mainly on the follicles, which stand out in bold relief from the surrounding mucous membrane. Their prominence is often exaggerated by a degree of atrophy of the intervening mucous membrane. This condition is known as *follicular pharyngitis*, granular pharyngitis, or clergyman's sore throat, the last title being applied on the supposition that it results from overuse or misuse of the voice. Destruction of the follicles with chemical caustics, the electric cautery, or the curette is often recommended; but when marked general atrophy of the mucous membrane coexists, it is unwise to attack them too vigorously. Careful daily cleansing with saline solution, followed by applications of ichthyol (twenty per cent in keroline, with gentle massage) or of Mandl's solution (iodin. cryst., kali iodid., āā gr. x.; glycerin, water, āā ℥ ss.), will give the best results. At the same time close attention should be given to the patient's habits and general health. For advanced atrophy (*pharyngitis sicca*) but little can be done beyond the use of mild antiseptic and detergent irrigations. A very common phase of chronic pharyngitis is a hyperplasia involving chiefly the lateral walls (*pharyngitis hypertrophica lateralis*) and manifesting itself in the form of red bands of thickened mucous membrane extending down either side of the pharynx behind the posterior pillars. There seems to be no propriety in describing it as an independent disease, since it is clearly a sequel of an abnormal state in the nasal or postnasal region.

Amygdalitis.—Etiology and Symptomatology.—Inflammation of the tonsils, with or without involvement of the pharynx, occurs in three forms: (*a*) superficial or catarrhal; (*b*) follicular or lacunar; and (*c*) parenchymatous. These represent merely different grades of intensity, and the last often becomes phlegmonous, constituting peritonsillar or circumtonsillar abscess or quinsy. In a very large proportion of cases pus formation takes place between the palatal folds at the upper border of the tonsil, producing a bulging tumor of the velum between the tonsil and the uvula. Œdema of adjacent parts, especially the uvula, is apt to be extreme. In exceptional cases pus forms in the tonsil itself and still more rarely behind or below it. Some authorities look upon tonsillitis in all its forms as a rheumatic phenomenon. Others regard it as an infectious germ disease. The presence of a great variety of micro-organisms in the throat of one affected with amygdalitis is undeniable, but precisely the same kinds of bacteria are found in those who are entirely free from symptoms of sore throat. It is not easy to explain why they should exhibit virulence in one case and not in the other, unless we suppose that, when one's system is depressed by being tired or chilled the normal protective power of the physiological secretions is lessened. No difficulty in diagnosis arises except in connection with a lacunar tonsillitis, when the secretion from the crypts spreads out over the surface of the tonsil in the form of a pseudo-membrane resembling that of diphtheria. In the latter, however, the false membrane is more embedded, is detached less readily, and is usually darker in color. The adjacent mucous surfaces are livid or purplish, whereas in follicular tonsillitis they are intensely red. Pyrexia and systemic depression may be very marked in either disease, but they are especially so in follicular tonsillitis. Inflammation of the cervical lymph nodes, albuminuria, and the presence of the Klebs-Loeffler bacillus in the exudate serve to complete the chain of evidence in favor of diphtheria. In its early stages acute follicular inflammation is easily distinguished, the mouths of individual crypts being plainly defined by accumulation of detritus and yellowish-white secretion which can be readily removed with probe or curette. The whole tonsil is turgid and red and the wall of the pharynx generally shares the hyperæmia.

TREATMENT.—Whether or no rheumatism is concerned in the etiology, these cases do well under the salicylates and alkalis administered internally as well as locally. The throat may be too sore to permit gargling, but douches and sprays of hot saturated sodium bicarbonate, combined with hot fomentations externally, are comforting. Tincture of iodine, or ten-per-cent carbolic-acid solution, applied to the lacunæ is helpful. Internally, the old-fashioned ammoniated tincture of guaiac or one of the modern coal-tar products (phenacetin and salol) may be used after the administration of a saline laxative.

Chronic inflammation of the tonsil may exist without much increase in size of the organ. It may not appear beyond the plane of the faucial pillars, but on close inspection the crypts are found in a state of irritation and choked with secretion. Little whitish-yellow pledgets or balls composed of mucus, epithelial débris, and many different kinds of bacteria occupy follicles, whence they may be removed with curette or from which they are now and then spontaneously expelled. These masses have a very bad odor and are a frequent cause of offensive breath. The subjective symptoms are rather indefinite. A vague feeling of uneasiness or a slight sensitiveness is about all that is complained of, except, of course, during an acute exacerbation, when the usual symptoms of acute tonsillitis are exhibited. At other times the subjective symptoms are rather out of proportion to the objective appearances, and it is in this type of case particularly that we have reason to suspect an underlying rheumatic diathesis. Otherwise there seems to be no sufficient cause for describing a rheumatic tonsillitis or a pharyngitis as an independent entity. Antirheumatic remedies administered internally, and antiseptic gargles, are of service. The gymnastics of gargling are beneficial through the muscular movements involved, apart from any medicinal virtue which the solution employed may possess. Of radical corrective measures the guillotine, punch, and snare are in many cases not available because of the small volume of the tonsil. The curette and the electric cautery are the most effective agents, but, if these are objected to, chromic acid or trichloracetic acid may be applied to the crypts with benefit. Care should be taken to avoid using an excess of the acid.

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Staphylotomy.

A train of distressing symptoms is sometimes excited, especially in nervous subjects, by an elongated uvula—a condition to which the laity has applied the expression "dropping of the palate." The patient is annoyed by a sensation of a foreign body in the throat, with a constant desire to clear the passage. There may be tickling and dry spasmodic cough, and at times vomiting is provoked. The frequent hawking adds to the irritation, and a general congestion of the pharynx and even of the larynx may supervene. In consequence the voice becomes hoarse and weak. On examination of such a case not much may be seen except what it is customary to call a "relaxed" condition of the parts. The subjective symptoms are those of a general chronic pharyngitis. In many cases excessive length of the uvula is the obvious cause of all the symptoms; in the majority it is rather a result of other abnormalities, nasal or postnasal. Often the uvula is not only long but thick, while in certain other cases its redundancy is not at once apparent owing to the unusual width and low attachment of the posterior pillars.

Whatever the function of the uvula, its entire ablation seems to have caused no ill effects, and, on the other hand, the beneficial results have often been great. In performing the operation we endeavor to preserve enough of the organ to assist in closing the upper pharynx during speech and in swallowing. Inasmuch as a hypertrophied uvula is usually symptomatic of other morbid conditions, these must first be relieved. This statement applies especially to nasal obstructions that interfere with breathing and drainage. Astringent applications accomplish little or nothing in long-standing cases. Here amputation is the only resource. Complicated instruments for the purpose, special scissors or uvulotomes, are superfluous. It is a simple matter to seize the tip of the uvula with forceps, draw it forward, and snip off with scissors as much tissue as may seem necessary. Thus the cut surface is made to face the posterior pharyngeal wall, where it is possibly subjected to less irritation in the act of deglutition. After the operation the mucous membrane is apt to retract in such a way as to expose the stump, which may continue sensitive for days or even weeks. To obviate this result Dr. W. E. Casselberry suggests a supplementary excision of the submucous tissues at a higher plane. The stump after a uvulotomy performed in this manner is said to be more tapering and flexible. A similar end is attained by adopting the plan of Dr. D. Braden Kyle, who removes a wedge-shaped portion of the tip by cutting obliquely downward and outward from the middle of the uvula to either side. The denuded surfaces may be sutured or may be approximated without stitching. The cold wire snare and the cautery snare are recommended by some, but are slower and more painful than cutting, and the danger of hemorrhage which they are supposed to prevent is insignificant. In spite of cocaine there is sharp pain at the moment of excision, and this pain may continue for some time as a neuralgic aching, to be relieved by applications of cocaine or orthoform emulsion, or by steam inhalation. If necessary, hemorrhage may be controlled by styptics or by compression of the end of the bleeding stump by clamp, forceps, or ligature.

Circumtonsillar Abscess.—The disease usually develops as a sequel of parenchymatous tonsillitis. Chills, high fever, extreme pain in swallowing, accompanied by the formation of a swelling of the soft palate just above the tonsil, and by tenderness and swelling of the lymph nodes at the angle of the jaw, comprise the prominent symptoms. At first, the palatal tumefaction is hard and tense, and there is at no time a very definite sense of fluctuation, even after softening has taken place. The reason for suppuration in this situation is found in the anatomical fact that the lymphatics of the tonsil unite here in a common trunk and then pass onward to the nodes in the neck. Resolution of a threatening abscess is wellnigh impossible. In cases in which this is believed to take place pus very likely escapes unnoticed by way of the supratonsillar fossa. Spontaneous opening may also occur through the anterior pillar. It is poor policy to wait for this phenomenon. Early evacuation is desirable, and, even if the presence of pus is not certain, scarification eases the way for spontaneous discharge. The latter is attended by some danger if it occurs during sleep or in one whose age or weakness precludes immediate ejection of the matter. In opening an abscess a thin-bladed, sharp-pointed bistoury, its cutting edge directed obliquely upward and inward, is inserted at the most prominent part of the palatal swelling near the upper border of the tonsil and a half-inch or more from the margin of the velum. A rule accepted by some is to make the incision bisect a line drawn from the base of the uvula to the last molar tooth. (Chiari.) The embarrassing experience of failing to find pus that is surely there may be avoided by making a free and deep incision. Sometimes the wall of an abscess that has just been missed by the knife may be ruptured by stretching the wound with a dressing forceps or blunt scissors. Pus being reached, it instantly exudes along the knife blade, owing to the tension within the abscess cavity. The lips of the incision tend to adhere and may have to be separated at intervals with a probe, while the lining membrane continues to secrete. Injecting hydrogen dioxide or astringents into the cavity is sometimes resorted to, but it seems about as well to rely upon gargling with a hot carbolized alkaline solution to expedite the emptying process. The relief of pain is immediate, and a patient who has been suffering for hours is quite content to be let alone. A few cases of serious hemorrhage from the wall of the abscess have been reported. In such a case the cavity should be laid well open and packed with gauze soaked in adrenalin chlorid. There is no risk of bleeding from any large vessel if the knife be used in the location and manner described, but in hæmophiliacs and in the presence of some vascular anomaly hemorrhage does not cease. In certain rare instances it has even been deemed wise to tie the carotid. A collection of pus elsewhere than in the classical situation may be harder to reach and slower in coming to the surface. An abscess at the bottom of a deep crypt is best exposed by incision of the body of the tonsil and breaking down the tissues with the finger or a stiff probe. It may rupture and discharge by way of a crypt or may be converted into a chronic abscess and persist until recognized and disposed of by some radical measure. It is noteworthy that certain persons are prone to attacks of quinsy as a result of seasonal changes or when they get run down in health. In the intervals the tonsil may not be conspicuously enlarged, but on close examination the crypts are found to be diseased and very likely in the supratonsillar fossa will be discovered a bunch of lymphoid tissue which is an especially favorite nidus of septic germs. The indication, in cases of this kind, is to eradicate every vestige of morbid tissue; otherwise, recurrences of amygdalitis, generally with phlegmon, are inevitable. The tendency to quinsy subsides after maturity,—*i.e.*, after atrophy of lymphoid structures has taken place in this region,—but a first attack is by no means unheard-of in elderly people. In these manipulations about the tonsil it is customary to use local anæsthesia, although its actual value under the circumstances is doubtful. In certain cases the employment of a general anæsthetic is required.

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Retropharyngeal Abscess.—Phlegmonous inflammation of the wall of the pharynx may originate in the cellular tissue or in the lymph nodes, the former thought to be more common in adults, the latter in children. Septic infection in this region may take place as a sequel of suppurative otitis, by way of the tonsils and of the lymphoid tissue in the vault, and doubtless by other routes. Traumatism, erysipelas, and the various exanthems are often responsible for its development. A large proportion of cases occur in children who are tuberculous and who suffer from some disease of the cervical vertebræ. The lymph nodes located along the lateral walls of the pharynx and lying in front of the vertebral column are very numerous. When inflamed, they may undergo resolution, but as a rule suppuration follows, the formation of pus sometimes taking place with extraordinary rapidity, and then again very slowly ("cold abscess"). The local disturbance and the general symptoms are more urgent in the former case than in the latter. Chills, fever, difficulty in swallowing, altered voice, and impeded breathing lead to inspection of the air tract, when a diffuse swelling of the wall of the pharynx is discovered usually on one side of the median line. In children, among the first symptoms noticed are a change in quality of voice (*cri de canard*) and a tendency to extension of the head, that position being taken to relieve impediment to breathing offered by the swelling. The disease is generally confined to the middle pharynx, but exceptionally it is located at a higher point, and again it may be situated so low down as to be exposed only by forced depression of the tongue or by the use of the mirror. The tumor is sensitive, elastic, and even fluctuating. On the contrary, the density of the wall of the abscess may mask its character. Thus it may be mistaken for a solid neoplasm, and cases are on record in which a suspicion of malignancy has been mistakenly confirmed by the microscope. (Goldstein.) Puncture or aspiration of the tumor should prevent an error of this kind. In my own experience a gumma of the pharyngeal wall, without a specific history, was supposed to be an abscess until it rapidly resolved under potassium iodide. In a young infant, in an aged person, or in one in bad physical condition the situation is most grave and calls for prompt interference. Death may ensue from inanition, asphyxia, or erosion of an artery. The question sometimes arises whether the abscess should be opened through the mouth or by an external cut. In most cases the former course is to be selected. When the collection of pus is extensive and situated very low in the pharynx, it may be best to evacuate and drain from the outside. When the abscess is not large and can be easily seen, it is a comparatively simple matter to open it through the mouth. It is well to have the patient on the side or so placed that he can be thrown forward on the face instantly the opening is made. Local anæsthesia is generally sufficient, and an incision with a sharp-pointed curved bistoury at the most prominent part of the tumor seldom fails to enter the abscess cavity. Escape of pus is encouraged by dilating the incision with blunt scissors or dressing forceps. In children and unmanageable subjects it is necessary to operate under general anæsthesia, and occasionally a preliminary tracheotomy is imperative. The patient should be placed on his back with the head well extended in order to prevent the entrance of pus and blood into the air tract. The risk from this source is considerable in infants, in the aged, and in the debilitated. Other dangers are from sepsis and hemorrhage. The former is to be obviated by thorough emptying and cleansing of the abscess, and the latter by firm packing of the cavity with sterilized gauze. Œdema of the glottis is a possible complication of abscess formation in this region, and a single case is on record in which sudden death at the moment of incision was attributed to reflex syncope from damage to the pneumogastric nerve displaced by the inflammatory swelling. The former is to be met with intubation or a tracheotomy; the latter condition can hardly be foreseen. Usually, if the incision is ample and the abscess cavity moderate in size, the case takes care of itself, with some restriction of diet for a few days. In the more aggravated cases attention must be given to drainage and to the causes which excited the pathological process. (For further details consult the article on Surgery of the Neck in Vol. VI.) The local treatment, if any, generally followed is the injection of the abscess cavity with iodoform emulsion or packing with iodoform gauze through an external wound. In many cases the underlying constitutional state is so bad that no tonic or hygienic measures avail to prevent a fatal termination.

IV. PHARYNGOMYCOSIS; KERATOSIS; VINCENT'S ANGINA, AND OTHER PHARYNGEAL DISEASES DUE TO THE ACTION OF MICRO-ORGANISMS.

Pharyngomycosis; Keratosis.—There are but few diseases so common and attended by such trivial symptoms, as benign pharyngomycosis, the literature of which is so rich. Views of its etiology and nature are equally discordant. There are two theories of causation, the parasitic and the chemical, and each of these has its firm supporters. According to the former the active agent is the Leptothrix buccalis, and the process is a genuine mycosis. The advocates of the latter view account for it by certain changes in secretion and regard it as a keratosis, the essential feature of which is a cornification of epithelium, the presence of a fungoid growth being purely accidental. A possible explanation of this divergence of opinion may be found in the suggestion that there exist two forms—one characterized by an abundant crop of leptothrix (mycosis) and the other by thickening and hardening of epithelium (keratosis). There seems to be no doubt that the leptothrix exists in normal throats and that in certain cases of mycosis epithelial changes predominate. The picture of a case of mycosis is unmistakable unless complicated by an exceptional degree of local inflammation. As a rule, there is no local inflammation, and the white mycotic tufts, sometimes soft and friable, at other times of horny consistence, protrude from normal or somewhat hyperplastic lymph follicles. Thus, the palatal tonsils furnish a favorite site for the growth, but it may be implanted in lymphoid tissue at the base of the tongue, in the vault of the pharynx, or in isolated follicles on the wall of the pharynx or elsewhere. The whiteness and prominence of the tufts have suggested the fanciful appellation "stalactites." When they are dragged from a follicle to which they adhere with tenacity, a few drops of blood are apt to follow. After it has apparently been completely removed, the fungus reproduces itself with astonishing rapidity and profusion. Within twenty-four hours it is sometimes as abundant as ever. On the other hand, for some reason unknown, spontaneous disappearance is often observed. In view of the few symptoms which it excites and of its obstinate resistance to treatment, save of the most heroic and radical character, one is almost persuaded to let Nature have sole charge. It not infrequently happens that a patient is quite unaware of there being any trouble with his throat until attention is called to it by the physician. Subjective symptoms may consist simply of a consciousness of discomfort, or of various perverted sensations, such as prickling, burning, a feeling of weight or of fulness, and so on. Inflammatory symptoms are not a part of the clinical history, and pain, redness, and swelling must be looked upon as simply coincidental. Reflex cough has been noted in several cases.

In the treatment of this affection many different drugs have been recommended. Most of them are useless. Tincture of iodine, hydrogen dioxide, carbolic acid, pyoktanin, and nearly all the astringents and caustics have been tried with more or less satisfaction. Success can be expected from no method that fails to reach every vestige of the fungus. Curative powers have been attributed to tobacco, and in at least one instance alarming toxic effects followed an application of nicotine. If the disease is confined to an enlarged tonsil, tonsillectomy is indicated. In general, the most permanent results follow the use of the electric cautery. No spot involved should be overlooked. In several cases rather serious inflammatory reaction has ensued from this procedure, but possibly the disaster may be chargeable less to the method than to the way in which it was used. If for any reason objection to electricity is raised, a chemical caustic should be selected. Of these, chromic acid and trichloracetic acid are most effective within safe limits. Repeated applications are necessary to control a tendency to reproduction. It would indeed be strange if an agent tried in almost every other known disease should be overlooked in this. So we are not surprised to hear that the *x*-ray has been used in mycosis, but with what results it is still too early to state. Disease of the teeth, catarrhal conditions, and digestive derangements must be corrected. In certain cases tonics, change of climate, and careful dieting are of service. On the whole, the disease is mainly of clinical interest and not of much pathological importance, except as regards confusion with follicular tonsillitis or with diphtheria. Typical cases admit of no error, while in doubtful ones an appeal to the microscope will furnish conclusive testimony.

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Ulcero-membranous Angina (Vincent).—It is only within recent years that a form of ulcerative lesion affecting the pharynx—to which lesion the terms diphtheroid, ulcero-membranous, or Vincent's angina have been applied—has been recognized as an independent disease, caused by a special spirillum and bacillus. Some doubt has been cast upon the etiological importance of these bodies by their discovery in other lesions and even upon parts in which no lesion was present, as well as by the difficulty experienced in attempts at cultivation in artificial media and by the failures to inoculate the disease in animals. Yet their presence in such large numbers during the height of the ulceration, and their gradual disappearance as healing takes place, seem to give them some significance. From its characteristic shape the bacillus has been named "fusiform bacillus." The ulceration covered by an adherent membrane often closely resembles a diphtheritic ulceration. It usually involves one tonsil, but may extend to the gums and the inside of the cheek, or is confined to the latter regions, where it simulates an ulcerative stomatitis. The process may either be quite superficial or it may penetrate to some depth, but even in the latter case repair takes place so perfectly as hardly to leave a trace of permanent damage. The ulceration is extremely sensitive and is attended by enlargement and marked induration of the adjacent cervical lymph nodes, which conditions are prone to persist for some time after the ulcer has healed. Systemic disturbance is seldom profound or at least is not in proportion to the local symptoms. The membrane clears off and the ulcer usually heals in two or three weeks under the use of simple antiseptic washes. Lugol's solution of iodine, methylene blue, hydrogen dioxide, and various other agents have been tried without demonstrating the marked superiority of any one of them in particular. Errors in diagnosis occur most often as regards syphilis. Absence of specific history, which of course by itself has little or no evidential value, resistance to antisyphilitic treatment, and the appearance under the microscope of the special organisms of Vincent's angina confirm the identity of the disease. In an elderly person a suspicion of malignancy might at first be suggested.

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Actinomycosis.—This rare and interesting disease is occasionally seen in the tonsils as hard nodules which finally soften and form small abscesses. The essential element in the disease is the ray fungus, which is introduced from without, finds its way into the wall of the pharynx or the body of the tonsil through some lesion of the mucous membrane, and is easily identified by aid of the microscope. The subjective symptoms may be insignificant or are mistaken for those of an ordinary tonsillitis. In the early stages, while the nodules are still very indurated, malignant disease might be suspected, but the absence of pain and of enlargement of the lymph nodes, and finally the discovery, in the lesion itself or in its secretion, of the characteristic yellowish-brown actinomycotic granules and of the ray fungus establish the diagnosis. As in syphilitic ulceration there is a good deal of surrounding brawny induration, but the undermined edges and flabby granulations of the actinomycotic ulcer, together with the numerous sinus tracks and independent pus foci scattered about, are typical. It is most important to recognize and exterminate the disease before it has spread to the alimentary canal or the respiratory tract.

Glanders.—Glanders is occasionally transmitted to human beings from the horse. In its ulcerative stage, which is preceded by more or less infiltration of the tissues, it may be readily mistaken for tuberculosis. Any doubt is dissipated by the existence of typical lesions elsewhere, by resort to animal inoculations, or by appeal to the microscope. The pathogenic bacterium of the lesion is the Bacillus mallei. The disease usually begins in the nose with symptoms of an acute rhinitis and is apt to invade the accessory sinuses. On the septum or turbinates are seen small nodules which finally suppurate and are attended by extensive infiltration of the cervical lymphatics. Ultimately, the disease may involve the wall of the pharynx or the tonsils. The prognosis is bad. In the few cases observed no treatment seems to have been effective. Benefit has been claimed from the internal use of potassium iodide and from the employment of antiseptic alkaline washes locally. A specific antitoxin (mallein) has been tried, but no decisive results have thus far been reported.

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Rhinoscleroma.—Rhinoscleroma is also a disease that reaches the pharynx from the nose, and yet, on the other hand, it may manifest itself primarily in the pharynx. It is said at times to originate in the salpingo-palatal fold, thence extending in all directions. The characteristic feature of the lesion is the nodular infiltration, of cartilaginous hardness, which slowly undergoes cicatricial retraction, with little or no previous ulceration. The result is often extreme deformity of the affected parts and stenosis of the passages sufficient to interfere seriously with deglutition and respiration. When, as is usually the case, the disease involves the nose and even the external parts, the disfigurement is excessive. When an ulcer forms, it is described by some writers as characteristically "cup-shaped." The lesion is distinguished from one of a syphilitic nature by its pronounced chronicity and by the fact that the distorting cicatrices are not preceded by much, if any, ulceration. Still further, the typical micro-organism (the bacillus of Frisch) is found in the cells of the morbid tissue, or in cultures. The treatment is merely palliative and consists of removal of enough tissue to relieve obstruction. Internal medication is powerless.

Herpes; Pemphigus.—The vesicular stage of herpes is of short duration owing to the constant maceration of the affected region. The individual lesions, when they are examined, usually appear as round, superficial erosions, one-quarter of an inch or less in diameter, with grayish-white surfaces and narrow bright-red areolæ. The area affected is often quite sensitive, and one may generally expect to find similar lesions on the inside of the cheeks and on the tongue, as well as on the external surface. The disease is looked upon as a neurotic disturbance and dependent upon some gastric derangement. The latter should be corrected and the use of bland alkaline pigments or gargles is indicated. The eruption may occur in successive crops, and several lesions sometimes coalesce to form quite an extensive denuded surface. In severe cases there is decided constitutional disturbance, together with itching, burning, and radiating pain in the pharynx. The flow of saliva is stimulated and the cervical lymph nodes are enlarged and sensitive. Arsenic; strychnia, tincture of aconite, and antirheumatic remedies have all been recommended by various observers for internal administration.

In pemphigus the chief symptoms characteristic of herpes occur in a much aggravated degree. The bullæ are larger and are often accompanied by a cutaneous eruption. Pemphigus may appear in an acute form or as a chronic disease extending over many years. It may develop in the course of syphilis or in connection with any debilitated systemic condition. The blebs may reach such dimensions as to embarrass breathing, and the soreness of the affected parts interferes with swallowing. Arsenic pushed to physiological effects seems to be the only remedy that has any influence on the disease. Dermatologists declare that pemphigus of the skin is not uncommon in the poorer classes of the great cities, but it is extremely rare for the disease to affect the mucous membrane of the alimentary canal, from mouth to anus (including the nares), and the serous surfaces of the liver, spleen, intestines and pleura, as occurred in a case recently reported by Cocks. Temporary relief was given in this case by evacuation of the bullæ within reach and the application of methylene blue, but the case terminated fatally after several recurrences, with no cutaneous manifestations whatever. Leucocytosis was found during the attacks, and indican was constant in the urine, the latter being regarded as the cause.

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V. ADENOIDS IN THE RHINO-PHARYNX; ADENECTOMY.

Lymphoid tissue is found normally at various points in the upper air tract. In the vault and down the lateral walls of the pharynx, between the palatal folds, and across the base of the tongue it forms an almost continuous circle to which the name "lymphoid triangle" or "ring of Waldeyer" (1884) has been given. Whatever may be the physiological function of lymphoid tissue it is obvious, from a clinical standpoint, that when diseased it has ceased to do its proper duty, and becomes, on the contrary, an avenue of infection, a source of local irritation, and a mechanical obstacle in the region which it occupies. The word "tonsil" is rather inappropriately used to designate these lymphoid collections, and that in the vault of the pharynx is often spoken of as the "third tonsil," the "pharyngeal tonsil," or "Luschka's tonsil." Although "adenoids" is an inexact term it seems best to retain it in describing these masses of lymphoid hyperplasia which are met with in the upper pharynx.

Etiology and Pathology.—The lymphoid tissue in the vault of the pharynx is subject to attacks of inflammation, during which it presents the usual phenomena of this disorder, and upon the subsidence of the inflammation the tissue may resume its original proportions and its former function. Such results do not occur after attacks which have been very intense or prolonged or have been frequently repeated. Under these circumstances structural changes take place and a permanent condition of hypertrophy and hyperplasia supervenes.

Lymphoid hyperplasia is often a sequel of one of the exanthems. It is frequently seen, for example, in persons affected with syphilis, and is often associated with some obscure constitutional disturbance or systemic dyscrasia allied to what was formerly termed "scrofula." This dyscrasia has been named by Potain "lymphatism." Not infrequently these local changes take place without antecedent signs of inflammation, and it is not an uncommon experience to meet with extreme lymphoid hyperplasia unattended by impairment of the general health. In one case there is a vitiated state of the whole body, and in another the lymphoid enlargement is merely a local condition. The morbid process may be limited to the epipharynx, but as a rule the lymphoid tissue in other regions is at the same time similarly affected. Thus, hypertrophied faucial tonsils usually accompany adenoids. The influence of heredity is undetermined, yet we often find several members of a family presenting this anomaly. Bad hygiene and improper diet might be expected to favor the development of this hypertrophy, but on the contrary it is by no means uncommon in those living in a most healthful environment. Damp and changeable climates, overheated and ill-ventilated houses, especially sleeping-rooms, are no doubt contributing causes. On the other hand, an excessively dry air is also believed to be pernicious. Too much stress cannot be laid upon impeded nasal respiration as a cause of both the formation and the recurrence of adenoids. An unnoticed injury or a neglected cold in the head in early life may lead to a deformity or an obstructing overgrowth in one or both of the nasal passages, and this obstruction compels mouth-breathing, with its evil consequences.

An intranasal obstacle to the air current inevitably causes rarefaction of the air behind it and leads to a state of chronic congestion which favors the development of adenoid vegetations.

There is strong evidence to support the belief that the tubercle bacillus may invade the system by way of a lymphoid follicle without causing marked local changes, yet there is no reason to believe that those affected with tuberculosis are especially prone to lymphoid hyperplasia. The uric-acid diathesis has been held accountable for adenoids. The use of this term, like that of malaria, often serves as a cloak for ignorance.

The condition termed "adenoids" is essentially a disease of childhood. After the age of fifteen the tissue tends to shrink. Dense, highly organized masses may persist after puberty, and in exceptional cases they are found quite late in life. The disease is equally frequent in both sexes. A few congenital cases have been reported, and in a nursing infant the condition may actually jeopardize life.

It is customary to attempt a classification of adenoids on a pathological basis, but the varieties of the lesion thus described are practically stages of the same process variously modified by peculiarities in conformation of the affected region or in the constitution or habits of the individual.

The relative proportion of cellular and connective-tissue elements in hypertrophied lymphoid tissue varies with the foregoing conditions and, moreover, is influenced by the frequency of acute inflammatory attacks as well as by the chronicity of the process.

In general, the younger the subject and the more recent the morbid process the more vascular and cellular is the adenoid mass. In old cases connective tissue predominates and the growth is dense and fibrous. In very young children, especially those suffering from some gastro-intestinal disturbance or local irritation, we observe a transient intumescence of lymphoid tissue owing to passive congestion. This swelling, however, disappears spontaneously or under simple sedative applications. A well-defined adenoid mass consists, therefore, of cellular elements embedded in a network of connective tissue (the retiform adenoid tissue of His), which is traversed by blood-vessels more or less numerous and covered by the mucous membrane common to this region. The thickness of the basement membrane and the number of epithelial layers vary widely.

Symptoms and Diagnosis.—The diagnosis of adenoids is frequently possible at a glance. The shape and peculiar expression of the face constitute what is called the *adenoid facies.* This type of face is not exclusively characteristic of this disease, since it may be present in almost any form of nasal or postnasal obstruction, and is sometimes observed when nasal breathing is little, if at all, impeded. A child with adenoids wears a dull, listless expression, finds mental concentration difficult, and hence is backward in school. This state of mental lethargy, supposed to be due to interference with the circulation or the lymphoid drainage of the brain, was named by Guye, of Amsterdam, *aprosexia.*

The external nose is apt to be small, the nostrils are contracted, the alæ collapse on inspiration, and the labio-nasal furrow is effaced. The transverse nasal vein at the root of the nose is often very prominent. The upper lip is short and retracted, exposing the projecting teeth of the upper jaw. The lower jaw recedes so that the alignment of the teeth is imperfect. The lateral diameter of the upper jaw is diminished and the height of the palatal arch is increased, the normal dome of the oral cavity being converted into a V-shaped or Gothic arch. It is a matter of dispute whether this deformity of the roof of the mouth is a result or a cause of the adenoid development. In extreme cases distortion of the thoracic wall in the shape of pigeon-breast occurs. With regard to this, likewise, the question arises whether it is a result of the labored breathing or of the general condition supposed to induce the lymphoid hyperplasia. The apparent hebetude exhibited by adenoid cases is in part explained by impairment of hearing. Ear complications, functional or organic, are the rule in adenoids, and a "running ear" in a child should always suggest a careful examination of the naso-pharynx. Nosebleed is a frequent symptom in these cases, even when the nasal stenosis may not be very pronounced. Purulent rhinitis, accompanied by eczema of the nostrils and lip, is often present. In view of the disturbed nights these children pass, it is natural that their general condition should suffer. Not only is sleep interrupted by labored breathing, but they are frequently wakened by bad dreams, "night terrors," so that continuous refreshing rest is impossible. Various reflex disorders are traced to adenoids, prominent among which may be mentioned laryngismus stridulus, asthma, hay fever, nocturnal enuresis, chorea, and epilepsy. Older children complain of headaches and asthenopia. Gastric derangement is very common, and in consequence the nutrition may be seriously affected. Among the rare sequels of adenoids are included abdominal hernia and prolapse of the rectum, the latter being regarded by some as an example of reflex exaggerated peristalsis. Next to the impeded breathing the most notable symptom of adenoids is the so-called "dead voice." The nasal consonants cannot be pronounced, and the voice is lacking in resonance. One thus affected is commonly referred to as "talking through his nose," whereas the reverse is actually the case. Cases have been recorded in which stammering and stuttering have been cured by removal of adenoids. Perversions of the sense of smell and of taste have been met with. Opinions differ as to the causative relation of adenoids to laryngeal new-growths, but it is reasonable to suppose that an abnormal air current, as well as the extraordinary effort in phonation imposed upon the larynx by nasal and post-nasal obstruction, may predispose to neoplastic development in that cavity.

The degree of subjective disturbance caused by an adenoid mass does not depend upon its size. One of large dimensions may be carried without complaint; on the other hand, a moderate growth in a contracted pharynx and in a child of nervous temperament may cause serious damage.

It is sometimes necessary to determine the extent and distribution of adenoids by digital examination as well as by inspection with the rhinoscope. (Fig. 403.) In very young and refractory children the latter is impracticable. When palpation is employed a mouth gag should be adjusted, or the examining finger should be protected by a shield of metal or rubber, or by pressing the cheek of the patient firmly between the teeth with a finger of the disengaged hand. The right middle finger for the latter purpose, and the left forefinger for examining, will perhaps be found most convenient.

A finger shield is objectionable for the reason that it interferes somewhat with the tactile sense. With the finger one recognizes a soft, pulpy, lobulated mass, occupying chiefly the fornix of the pharynx and imparting a sensation which has been likened to that given by a bunch of earthworms. Owing to the vascularity and irritability of the tissue, the finger on withdrawal is smeared with blood. This is not the case in examining a normal pharynx unless extraordinary roughness is used. The employment of palpation is so disagreeable and terrifying to little patients that it is well to avoid it if a diagnosis can be made otherwise. It is surprising what can be done with the rhinoscopic mirror,

Fig. 403.—Adenoids in the Rhinopharynx. (After Gruenwald.)

even in the young and timid, by the exercise of tact and patience. It should be borne in mind that the picture in the mirror as to the amount of morbid tissue is somewhat deceptive owing to foreshortening. More is generally removed at the time of operation than the mirror had previously disclosed. Hence an advantage of supplementing inspection by palpation. Various devices in the form of palate hooks and retractors (Fig. 404) have been suggested with a view of facilitating posterior rhinoscopy. Unfortunately, they work best when least needed. An irritable pharynx resents the presence of these instruments and it is not advisable, as a routine custom, to obtund sensation by the use of cocaine. There are two objective appearances thought by some to be pathognomonic of adenoids:—The first is seen on anterior rhinoscopy, and consists of rugæ or thickened folds of mucous membrane running along the floor of the nostrils and partly occluding the inferior meatus; the second is a similar thickening of mucous membrane on the lateral walls of the oro-pharynx, the so-called "lateral bands." These folds of thickened membrane are apt to endure to adult life after the lymphoid tissue may have disappeared by atrophy.

Treatment.—Although the condition had been in a measure recognized before his day, we owe to Wilhelm Meyer, of Copenhagen, the first full appreciation of the significance of adenoids and the establishment of treatment upon

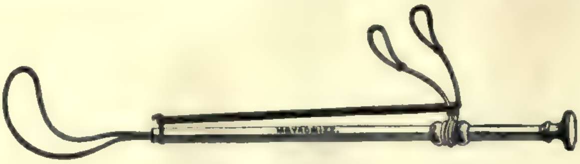

Fig. 404.—White's Palate Hook.

a rational basis. He realized the futility of medication and the necessity of instrumental interference. In the desire to escape the latter alternative many suggestions have been made, chiefly with the idea of promotiong absorption of the hypertrophied tissue. Internal treatment, local applications, and finally breathing exercises have in turn been vaunted in accordance with the fad of the period. These measures may do a limited amount of good by improving the general health, but experience shows that a well-marked case of adenoids is to be cured only by thorough surgical removal of the hyperplastic tissue. In the early operative work the growths were attacked with Meyer's small ring knife passed through the anterior naris and guided by the finger introduced behind the velum. It was soon found that they could be more effectively removed by curved instruments passed through the mouth. In order to expedite the operation, the size and grasp of the instruments have been gradually increased until to-day we are offered a large assortment of adenoid forceps and curettes, amply sufficient to suit the whim of any operator. In subjects under one year, or possibly two years, of age, the masses are so soft that they may be crushed and scraped away by the finger nail, but the method does not commend itself as being radical or aseptic. An artificial nail of metal is but a slight improvement on the natural. Disappointment is apt to follow such a crude method of operating. If lasting results are to be secured the cardinal principle to be observed is to remove every vestige of lymphoid tissue that can be identified. This cannot be accomplished by means of the finger alone, and we are compelled to admit that the majority of so-called recurrences are a sequel of incomplete operation, by this or some other method.

Destruction of the vegetations with chemical caustics or the electric cautery should be undertaken only in the presence of urgent symptoms and of contra-indications like hæmatophilia or a refusal on the part of the patient to be cut. When these agents are used the palate should be held forward by means of a palate hook (Fig. 404), or an elastic ligature or flexible catheter may be passed through the nose and drawn out of the mouth, its ends being tied over the upper lip. Moreover, the applications must be carefully made under guidance of the rhinoscopic mirror. In preparation, the region should be thoroughly cleansed of secretion and dried.

There are three important questions to be decided when an adenectomy is to be done:—1. Choice of anæsthetic, general or local; 2. Position of patient; 3. Selection of instruments—or the mode of operation.

It is foolish to deceive a patient by saying that removal of adenoids is not painful and that anæsthesia is superfluous. Some exceptionally stolid subjects make little or no objection, but to the majority the pain is extreme and the nervous shock is often quite lasting. In children local anæsthesia is impracticable and in fact it is not thoroughly satisfactory at any age. A general anæsthetic places the patient under perfect control and permits a radical operation, such as is not feasible in a struggling, resisting child. That one should be chosen which is known to be safest and most rapid in action. Bromide of ethyl is used by a limited number, but it is not yet proven to be free from risk. Chloroform is especially dangerous and should never be used in lymphatism. Nitrous oxide gas alone produces rather transient effects, but when it is followed by ether we have in these two agents an ideal combination. Nitrous oxide gas is agreeable to the patient and rapid in action, and such a small quantity is required that unpleasant after-effects are seldom experienced. Its relative safety is beyond question. A somewhat elaborate outfit is needed for its administration and a skilled anæsthetist should be in charge. The latter provision should be enforced regarding all forms of anæsthesia. Ethyl chloride is reputed to be safer than the bromide and may be substituted for nitrous oxide as a preliminary to ether. Administered by the drop method on a Ferguson inhaler it seems to act rapidly and to be safe. Its use is inadvisable when the lumen of the larynx is much contracted by swelling, œdema, or spasm.

So far as the actual operation is concerned, three different positions of the patient are seriously advocated: (a) the upright; (b) on the side; and (c) on the back. The chief reasons given for favoring the first are that it retains the relations of operator and patient to which we are accustomed in routine work, and that it allows blood and débris to escape forward rather than pass into the stomach or lower air tract. Moreover, the loss of blood is naturally somewhat less with the body erect; and, finally, there is supposed to be less danger of clots accumulating about the orifices of the Eustachian tubes and exciting irritation which might be transmitted to the middle ear. These reasons seem to be based on theoretical considerations rather than on practical experience. The natural drainage of the naso-pharynx is so good that ear infection after adenectomy is the rarest of accidents. In the partial anæsthesia employed the reflexes are not abolished, so that there is practically no danger from inspiration of foreign matter, while that passing into the stomach does no harm and is usually ejected by vomiting before full consciousness is recovered. The loss of blood is seldom of much consequence in these cases, and the convenience of the operator as regards position is wholly secondary. As a matter of fact, one of average dexterity is able to adapt himself to almost any position. Anæsthesia is induced with the patient lying down, and he is gradually brought to a sitting posture. The side position offers the advantage that the dependent cheek serves as a reservoir for blood that does not escape by way of the nose, and

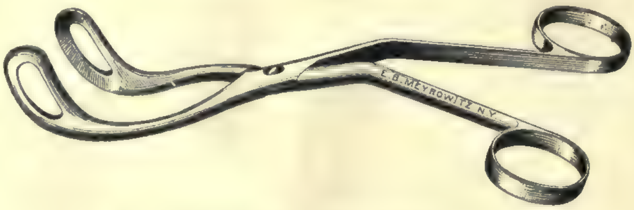

Fig. 405.—Knight's Adenoid Forceps.

little if any is swallowed or inspired. Manipulations in this position may seem awkward, but, as an offset, we are reliably informed as to the amount of primary hemorrhage and the danger of secondary hemorrhage is lessened by the freedom from emesis usually provoked by efforts of the stomach to get rid of accumulated clots. All things considered the recumbent position, with the head in line with the body or slightly dependent, is most suitable. The undeniable fact that it favors hemorrhage is not as a rule a very serious objection, since the loss of blood is speedily compensated by the improved general condition following the operation. The greater risk of blood and fragments of tissue getting into the larynx in this position is not present if profound anæsthesia

Fig. 406.—Brandegee's Adenoid Forceps.

be avoided. When the reflexes are preserved foreign matter is usually promptly expelled by the act of coughing.

In selecting instruments for adenectomy it is well to keep in view the elements of safety, thoroughness, and celerity. It is desirable to operate expeditiously and with as little handling of the parts as possible, in order to curtail the period of anæsthesia and lessen the damage to normal structures. Forceps and curettes, some cutting laterally and others antero-posteriorly, with generous cutting edges, are recommended. Some of the excessively powerful forceps sold in the shops should be discarded, since many of the accidents, to be referred to elsewhere, are attributable to the clumsiness of the instrument rather than to that of the operator. The patient having been anæsthetized, a mouth-gag is inserted on the left side, and the operator, standing on the right, drags the palate forward with his left forefinger and introduces a large-bladed lateral cutting forceps well into the nasopharynx. (Figs. 405 and 406.) The finger is now withdrawn and the forceps blades are opened, pressed forcibly into the vault, and firmly closed. Then by a twisting, dragging movement the main mass of the growth is removed. Immediately a medium-sized curette of the

FIG. 407.—Gottstein's Adenoid Curette.

Gottstein or Beckmann pattern (Fig. 407) is used to smooth down any roughnesses, and the patient is turned on the side to let the blood drain. When the bleeding has begun to subside the patient is replaced upon the back and the field of operation is explored for tabs or projections that may have eluded the instruments. These should be removed with small forceps or a curette under guidance of the finger. The lateral walls in the neighborhood of the Eustachian tubes, the fossæ of Rosenmueller, the choanæ and the margin of the nasal septum are to be examined with care, since in these situations small deposits are apt to be overlooked and to make trouble in future. Some operators prefer the cold wire snare, passed along the floor of the nose or through

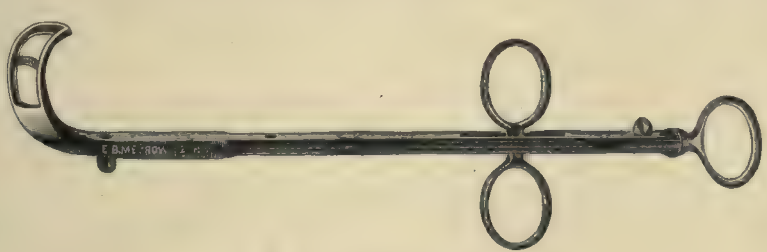

FIG. 408.—Schuetz's Adenotome.

the mouth behind the velum, while others choose the adenotome or guillotine. (Fig. 408.) Neither of these instruments seems capable of effecting complete eradication, unless the morbid growth, as is rarely the case, is confined strictly to the roof of the nasopharynx. In the regions referred to above, especially the choanæ, the straight cutting forceps of Ingals is very effective, so much so that its employment for the entire operation is advocated by Freer. This instrument is introduced through the anterior nares, its blades being guided by the finger passed behind the velum.

In the removal of adenoids, especially without anæsthesia and in fractious children, certain accidents may occur for which it is well to be prepared. The gravest of these is hemorrhage. Usually bleeding ceases spontaneously in a few minutes. In some cases the first intimation we have to the contrary appears in sudden pallor, a flickering pulse, and other signs of collapse, and measures for the control of the bleeding must be adopted. The list of so-called astringents offers nothing very reliable. Perhaps the best of these is a saturated solution of tannic acid, three parts, and gallic acid, one part. Pledgets of gauze soaked in this solution may be grasped with the adenoid forceps and pressed firmly into the vault in contact with the bleeding surface. Adrenalin chloride (1:1,000) may be instilled, syringed, or sprayed through the anterior nares. In moderate cases these applications will suffice. In others it may be necessary to plug, as for epistaxis, a somewhat larger tampon being required than would ordinarily be used in the posterior nares. A history of hæmophilia may not have been obtained, or, strangely enough, may have been concealed. Under these circumstances the situation is most serious and all efforts to check the hemorrhage may prove ineffective. In addition to local treatment, absolute rest with the head elevated should be enjoined, the extremities should be ligated, and opium, adrenalin, ergot, or calcium chloride or lactate should be administered internally. Children with a history of otitis should be handled with special gentleness and care, yet a "running ear" is not a contra-indication to operation. On the contrary, adenectomy may be essential to the cure of an otorrhœa. Carelessness or undue roughness in manipulation of instruments may involve danger to the septum, the Eustachian cushion, or the velum, or may result in stripping up the mucous membrane and exposure of the muscular planes. The last-mentioned may be followed in a few days by torticollis, a complication that always excites anxiety but usually disappears as repair progresses. A rent in the soft palate may need to be closed by sutures.

In view of the benefits which it confers and of the possible complications which may occur, it is unwise to regard adenectomy as an insignificant operation. At least two points should be kept in view: first, to remove thoroughly the morbid tissue, and, second, to avoid unnecessary preparatory and post-operative interference.

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VI. HYPERTROPHIED FAUCIAL TONSILS; AMYGDALECTOMY.

For clinical purposes enlarged faucial tonsils may be divided into soft and hard, the former sometimes called adenoid, the latter fibrous. They are practically stages, or degrees, of the same pathological process; hence we are more likely to find the former in children and the latter in later life or after repeated attacks of inflammation.

Etiology and Diagnosis.—Many cases even of extreme hypertrophy give no antecedent history of inflammatory attacks, and the etiology is often most obscure. In others there is distinct evidence of struma, or a family record of tuberculosis. Bad hygiene and deficient food encourage the development of such hypertrophy, but enlarged faucial tonsils are often seen in children brought up under most favorable conditions. They are frequent sequels of one of the exanthems and may be associated with a constitutional dyscrasia, inherited or acquired. Evidence is abundant that the tonsils may serve as avenues of infection without themselves showing pathological changes of importance. The degree of enlargement varies within wide limits. The tonsils may protrude and actually meet in the middle line, or even become adherent. Then, again, hypertrophy may be considerable and yet not be apparent through the open mouth on mere inspection, since the tonsil lies deeply buried in its fossa, or is concealed by an adherent anterior pillar ("plica tonsillaris"). A state of things not suspected when the parts are quiescent is often disclosed by exciting the act of gagging, which brings the tonsil into full view by rotating it on its vertical axis. Furthermore, palpation with a probe and the finger should be practised as a matter of routine in order to obtain information as to the size and consistence of the gland. The use of the mirror also should not be neglected. The shape of the hypertrophied tonsil varies greatly. Sometimes it is smooth, uniform, and globular. In other cases it is lobulated, ragged, and subdivided by deep fissures. Sometimes the tonsil seems to be bilobed or divided into two parts by a transverse furrow, probably the site of the intratonsillar fold which originally separated the two independent masses of which the tonsil is composed. The tonsillar crypts are often dilated and at their mouths appear yellowish plugs of secretion which are expelled or are removed at intervals. They emit a foul odor and are a frequent cause of bad breath. Under certain circumstances it is difficult to differentiate this condition from a mycosis or even from diphtheria, and a resort to the microscope may be necessary, the discovery of the characteristic leptothrix in one case, and of the Klebs-Loeffler bacillus in the other, furnishing conclusive evidence. An excessive proportion of salts in the secretion of the crypts may doubtless lead to the formation of a concretion or tonsillar calculus. Bone in the tonsil, a rare occurrence, may be a vestigial remnant of the second branchial arch, or a result of metaplastic changes.

Symptoms.—The amount of disturbance excited by hypertrophied tonsils depends in part on the relative dimensions of the pharynx, but more especially on the constitution and temperament of the patient. Now and then we see extremely large tonsils in an apparently perfectly healthy child who has never had a sore throat. On the other hand, tonsils of moderate size may be subject to frequent attacks of acute amygdalitis and a source of constant annoyance.

Their most conspicuous effect is upon speech, which is thick and lacking in resonance. When breathing is impeded, the patient instinctively forms the habit of protruding the lower jaw in an effort to drag the tonsils away from the opening of the glottis. The various deformities of the face, of the nasal fossæ, of the palatal arch, and of the thoracic wall, often observed in these cases, should be ascribed in part to the associated adenoid hypertrophy and probably in a measure to the underlying lymphoid diathesis (lymphatism). Very often deglutition is impeded; a child is prone to swallow the wrong way or regurgitate food through the nose. Cough and a number of reflex disorders, some of them genuine, have been ascribed to enlarged tonsils. The voice may be hoarse in consequence of a chronic laryngitis dependent upon the local irritation or upon enforced mouth-breathing. A similar condition results from voice strain, without marked hyperæmia of the larynx, extra labor being thrown upon the laryngeal muscles by the mechanical obstacle offered by the hypertrophies. Earache is sometimes complained of, but for this an adenoid hyperplasia is more likely to be responsible. The anterior cervical lymph nodes may be enlarged and sensitive, especially if the tonsillar lacunæ are much diseased and clogged with detritus.

Prognosis.—The advice to let a child "outgrow" hypertrophied tonsils is still sometimes heard. Whatever useful function normal lymphoid tissue may be credited with, we cannot conceive that it is capable of performing this function when it is in an hypertrophied state. Enlarged tonsils are a cause of local irritation and an inviting resting-place for all kinds of pathogenic germs. Moreover, in the event of infection they certainly diminish the chances of recovery. No doubt many children carry these impediments with little or no disturbance, and the tendency to atrophy, as the period of maturity approaches, is unquestioned. Yet in the mean time serious risks are incurred,—risks which are obviated by a resort, with almost absolute safety, to modern methods of extirpation. In rare cases after tonsillectomy a curious tendency to recurrence is manifested. Whether this is due to imperfect removal or to a special proclivity to lymphoid hyperplasia, is hard to say. It is met with in children, and, in some cases at least, seems to be a result of failure to release an adherent pillar. Its occurrence in adults may be inexplicable, unless we accuse a gouty or rheumatic diathesis. At any rate, it constitutes, together with various other alleged reasons, no valid argument against excision of tonsils.

Treatment.—Surgical measures offer the only reliable resource in the treatment of hypertrophied tonsils. In a small number of cases a limited amount of reduction is accomplished by tonics and good hygiene when the general health is impaired; or by local applications if the tonsil is soft and vascular. There still prevails a remarkable dread of hemorrhage in connection with the use of the knife in the tonsillar region, but this dread is not justified by clinical experience. The possible sources of hemorrhage are numerous, but a careful study of the anatomy of the parts proves that normally no large blood-vessel is within the danger zone. The carotids are separated from the capsule of the tonsil by several muscular planes as well as by more or less fat and connective tissue. The main source of trouble is a large tonsillar artery, derived from the ascending palatine branch of the facial. When this vessel is divided by a cut made through the middle of a fibrous, inelastic tonsil, its walls do not readily retract. For this reason it is safer to make an excision as complete as possible. A tonsil which appears to be abnormally vascular does not always bleed very much, and it is not easy to anticipate vascular anomalies. Marked pulsation is suggestive of a large nutrient artery or of unusual proximity of

Fig. 409.—Knight's Electric Tonsil Snare.

some large arterial trunk or an aneurism of the internal carotid artery. Hæmophilia, if known to exist, may perhaps be controlled by a course of calcium lactate (gr. xv.–xxx. dissolved in water, three times a day). Unfortunately the patient may be ignorant of it or conceals it from the surgeon. In cases of this kind it is advisable to avoid a cutting operation except in an emergency. In hæmophiliacs, in a patient who refuses to be cut, and when vascular or anatomical abnormalities are recognized, we may have recourse to chemical caustics or the electrical cautery. Of these agents the latter is preferable, but either is tedious and is likely to be followed by a good deal of reaction.

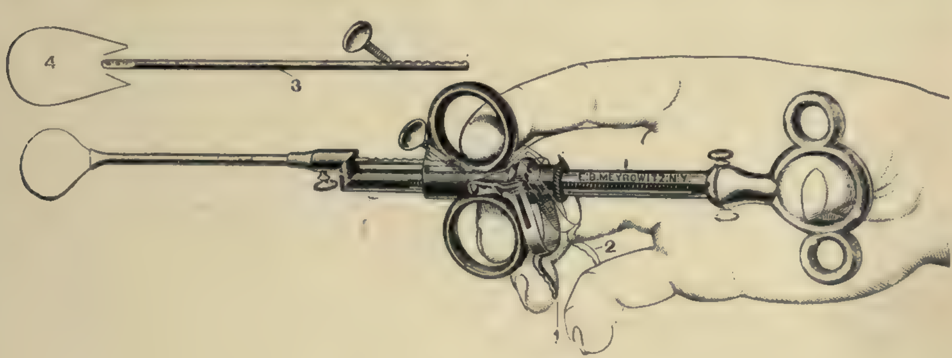

Fig. 410.—Farlow's Tonsil Snare.

Moreover, they give no absolute insurance against hemorrhage, several cases of bleeding on separation of the slough having been observed. Of chemical caustics London paste (equal parts of caustic soda and unslaked lime) is the best. The electric cautery may be used by puncture, snare, or dissection with the cautery knife. In spite of cocaine the process is painful. The cautery snare, introduced by Middeldorpf in 1854, can be conveniently used only in prominent, somewhat pedunculated tonsils. Difficulty in adjusting the loop may be overcome by the use of irido-platinum wire or by the aid of a fenestrated wire carrier intended for holding the loop at the base of the tonsil (Fig. 409). A revival of the ancient and barbaric custom of tearing out the glands with the fingers, as recently proposed, will hardly be greeted with enthusiasm, and the old plan of tying a ligature around the base of the tonsil and allowing the gland to slough off has been improved upon in modern times by the perfection of the cold wire snare (Fig. 410). The bistoury and various forms of scissors are preferred by some operators, but have little to recommend them. The tonsil punch (Fig. 411) is a very useful instrument, especially for seizing deep-seated masses and for clearing out the supratonsillar fossa. In most cases the

Fig. 411.—Farlow's Tonsil Punch.

instrument of choice is a guillotine or amygdalotome of the Mackenzie or Mathieu pattern (Figs. 412 and 413). The latter is provided with a fork for dragging the tonsil from its bed. The former is stronger and simpler, and the act of gagging excited by its presence in the fauces, together with counterpressure made externally, may be relied upon to carry the tonsil well into the grasp of the instrument. With a Mackenzie tonsillotome for the main operation and a tonsil punch for removing remnants, if necessary, it seems possible to accomplish all that can be required. As to the employment of a general anæsthetic and the proper position of the patient during the operation, what has been said under "Adenoids" applies equally to the faucial tonsils. General anæsthesia in children and local anæsthesia, if any, in adults, should be the rule.

If both tonsils and adenoids are to be removed, it is better to get rid of the former first.

In children the following method of using the Mackenzie guillotine is advised. It is customary to take out both tonsils in quick succession, usually the right first. The usual precautions as to diet, etc., having been taken, the child is anæsthetized in the recumbent position with gas-ether, which is believed to be the safest, most expeditious, and most agreeable combination. A Denhard or other suitable gag is inserted on the left side. The open tonsillotome is grasped in the left hand, passed into the mouth as would be a tongue-depressor, turned,

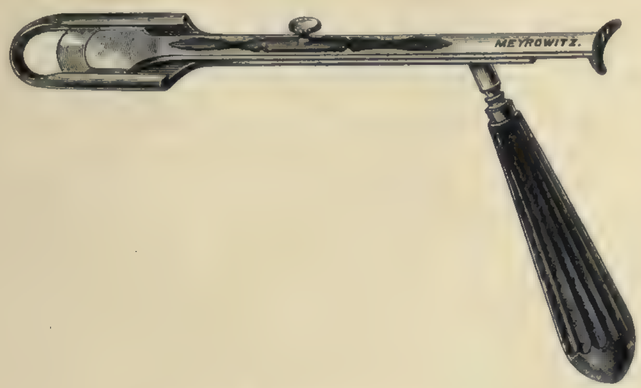

FIG. 412.—Mackenzie's Tonsillotome.

and pressed firmly over the base of the tonsil with the forefinger of the right hand. At the same time pressure is maintained externally by the hand of an assistant. The blade is at this moment pushed down by the thumb of the left hand and the instrument is instantly turned and withdrawn together with the excised tonsil. Without delay the left tonsil is removed in a similar way, the process being exactly reversed; that is, the instrument is held in the right hand and pressure on the shaft is made with the left forefinger. The second

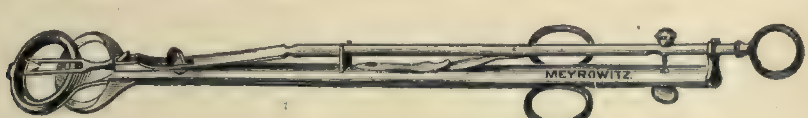

FIG. 413.—Mathieu's Tonsillotome.

tonsil having been disposed of, the child is promptly turned on the side to allow blood to escape by the mouth. No anæsthetic is required after the first, and narcosis should not be profound. A little more may be needed if adenoids also are to be removed at the same sitting. Thus the patient is spared much alarm and shock, and the operator is permitted to do his work with precision and deliberation. The anæsthetic should be entrusted only to an expert. Chloroform should never be permitted in these cases. The satisfaction experienced with the method described has been so great that one is not strongly tempted to experiment with others.

The *after-treatment* of these cases comprises care as to diet, exercise, and use of voice. Fluid or semi-fluid food only is given, and avoidance of excitement, physical and mental, is enjoined. If for any reason the use of a spray or gargle seems necessary, a mild antiseptic solution should be selected. Occasionally measures to control hemorrhage are indicated. A sharp secondary hemorrhage may occur at any time within a week or ten days, or a continuous oozing may finally be betrayed by vomiting of blood accompanied by general signs of collapse. At this point, or if the patient grows faint, the bleeding is likely to cease and with care may not recur. Moderate bleeding may be checked by mopping the surface with a strong solution of tanno-gallic acid (tannic acid, three parts, to gallic acid, one part), or the patient is directed to swallow a little of the solution, the local as well as the systemic effects being thus obtained. Cold affusions upon the neck and face and gargling with adrenalin-chloride solution may be effective. If the bleeding point can be identified, it is

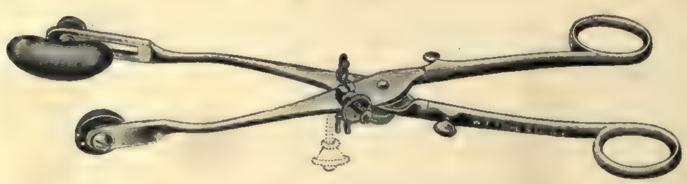

Fig. 414.—Mikulicz-Stoerk Tonsillar Hæmostat, modified by Harmon Smith.

seized with forceps and the vessel occluded by torsion, or the whole stump is transfixed with a tenaculum and twisted, as suggested by Levis, of Philadelphia. A ligature may be applied, or the loop of the cold snare may be tried.

The foregoing suggestions are by no means easily carried out in an unmanageable subject. The same is true of the electric cautery or the Paquelin cautery. The co-operation of the patient is essential. It has been proposed to suture firmly together the pillars of the fauces. The purse-string ligature of Dawbarn may be feasible in some cases. In general, pressure with the finger or with one of the various tonsil hæmostats (Mikulicz-Stoerk, Fig. 414) is most reliable. Ligation of the supplying artery in the neck, preferably the external carotid between the superior laryngeal and the ascending pharyngeal, should be looked upon as a last resort which seldom needs to be considered. Internally, agents tending to calm excitement (especially opium) and lessen arterial tension are indicated. The anæmic state resulting from the loss of blood may require attention.

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"Scissors in Excision of Tonsils," *Therap. Gazette*, Mar. 15th, 1895.—Fuller, in *Amer. Jour. Med. Sci.*, 1888, p. 357.—G. M. Lefferts, in Trans. Amer. Laryngol. Assn., 1881.

VII. THE LINGUAL TONSIL.

The lingual, sometimes called the fourth, tonsil (Fig. 415) is a mass of lymphoid tissue running across the base of the tongue behind the circumvallate papillæ. It seldom asserts itself in childhood, but is very prone to create disturbance in adults and especially voice-users. It is subject to acute inflammatory attacks like other lymphoid collections and may even undergo suppuration. Many cases reported as abscess of the tongue are doubtless of this character. Acute derangement may follow exposure in one who is in poor general health, or may be caused by the presence of a foreign body. It is to be treated on general principles by purgatives and antiphlogistics. If pus formation occurs, early incision is necessary. The suffering of the patient is often extreme. The whole tongue is swollen so as to protrude from the mouth, and is covered with leathery fur. Saliva dribbles constantly, since swallowing is almost impossible, and the breath is horribly offensive. Chills, fever, and other signs of sepsis are exhibited. The jaws may be fixed and so close together that great difficulty is found in making an examination as well as in using a knife for the purpose of evacuating the abscess. Owing to the proximity of the larynx the concomitant œdema may assume threatening proportions.

Fig. 415.—The Lingual Tonsil. (After Gruenwald.)

Hypertrophy of the lingual tonsil is best seen with the laryngeal mirror. In extreme cases the lobulated masses composing it are made plainly visible by simply protruding the tongue. The symptoms excited by the condition are often very pronounced. A vocalist or public speaker complains that the voice tires and becomes hoarse. The sensation of a lump or foreign body, causing a constant desire to swallow, may be present. A tickling irritative cough is often a source of annoyance.

In mild cases relief is given by painting the root of the tongue with tincture of iodine or with a strong astringent. In others reduction of the overgrowth by means of the electric cautery is required. In view of the subsequent soreness it is well to burn not more than two or three points at one sitting, and care should be taken to guide the electrode with the mirror and avoid touching the epiglottis. Excision with the lingual guillotine, a curved instrument constructed on the principle of the amygdalotome (Fig. 416), has been followed in several instances by rather alarming hemorrhage, which in this situation is somewhat difficult to control. The danger may be averted by the use of the cold wire snare. Aside from the danger of hemorrhage excision with the guillotine is the operation of choice.

Lingual varix is frequently associated with lymphoid hyperplasia and sometimes occurs independently. The enlarged and tortuous veins are readily seen in the mirror. The condition is of but little moment unless during a paroxysm of coughing a vein should rupture and give rise to hemorrhage. Under these

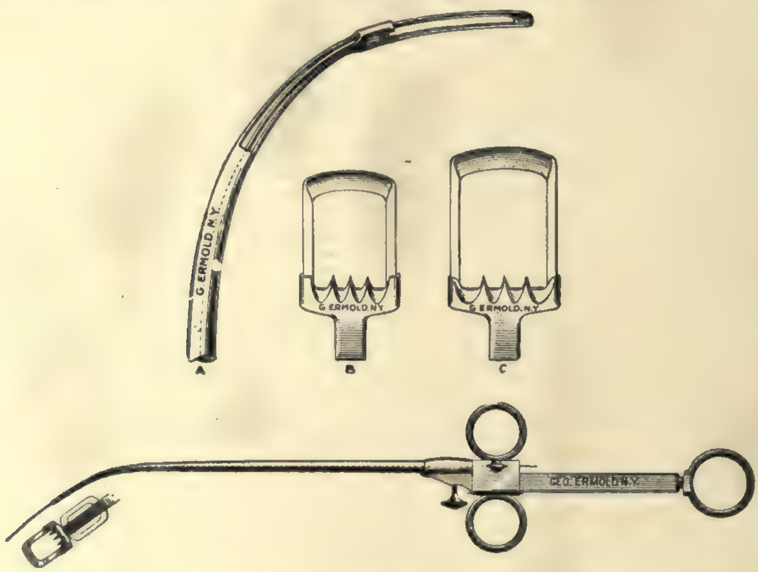

Fig. 416.—Showing Curve and Sizes of Myles' Lingual Tonsillotome.

circumstances it is a satisfaction to be able to assure the patient, who is naturally much disquieted, that the source of the bleeding is not the lungs.

The relation of the follicles at the base of the tongue to syphilis seems to have been first noted many years ago by Virchow. The subject has recently been carefully studied by Dr. N. B. Potter, who concludes that advanced atrophy of the lymphoid structures in this region in a person under fifty years of age is a reliable sign of syphilis. The condition is determined by palpation and not by the mirror alone.

VIII. SYPHILIS.

Syphilis is met with in such unexpected quarters, it sometimes pursues such an erratic course, it simulates so many other diseases, and is at times so obstinate and perverse under treatment that its study is full of interest and perplexity. The evolution of hereditary syphilis is more irregular than that of the acquired form. Unmistakable signs may appear at birth or the disease may declare itself for the first time in a full-grown child by interstitial keratitis, Hutchinson's teeth, general enlargement of lymph nodes, and destructive ulceration in the air tract. Distorting cicatrices and structural defects in the wall of the pharynx bear witness to an old ulcerative process that may have exhausted itself and undergone spontaneous repair. The thick, white, radiating scars are typical. Occasionally the bone is involved, and there are on record cases in which nearly the whole of the body of the sphenoid was exfoliated, the cranial cavity invaded, or the vertebral column attacked, with exposure of the spinal cord. In rare cases such a process is rather rapid, the disease assuming a malignant type and resulting fatally within a few weeks or months. It has been observed by Dr. J. N. Mackenzie, of Baltimore, who has given the subject of hereditary syphilis much careful study, that a sort of antagonism exists between certain exanthemata, especially scarlatina, and specific ulcerations of the air tract. The latter often heal in the course of the febrile affection, but sometimes recur as the acute symptoms disappear. The condition of marasmus which children with hereditary syphilis often manifest needs to be combated by the use of tonics, careful diet, and hygiene, as well as by the classical antisyphilitic treatment. The primary sore of acquired syphilis has been seen in the pharynx, and especially on the tonsil, so many times that it has almost ceased to be regarded as a novelty.

Modes of infection are various. Eating and drinking utensils, kissing, nursing from an infected person, sexual perversion, and unclean surgical instruments have been accused. Inoculation of the Eustachian cushion is said to have followed the use of an infected catheter.

In itself a chancre of the upper air tract may present no features by which it may be identified. In the case of the tonsil a small indolent ulcer, with raised everted edges and indurated base, which resists simple treatment and is not a source of much discomfort, may excite suspicion, but we must often await the development of a lymphadenitis and a cutaneous eruption for confirmation of the diagnosis. Absence of a history of exposure should never be considered. Possibly the initial lesion occurs in this region more often than supposed, owing to the trifling disturbance which it creates and the consequent neglect of careful inspection. At about the time when a skin eruption appears the fauces show a diffuse or mottled erythema which differs from a simple erythema in being more livid or purplish in hue and in being sharply limited at the junction of the velum with the hard palate. Sore throat may not be marked enough to attract attention.

Local treatment is seldom required for either of the foregoing; at most, a carbolized alkaline gargle may be thought necessary. As soon as the diagnosis is made, a mercurial course should be instituted, and mercurial fumigations of the fauces will be found beneficial.

The most common as well as the most dangerous lesion, in view of contagion, of the so-called secondary stage is the mucous patch. Its appearance is often likened to that caused by touching the surface with a strong solution of silver nitrate. The lesion is a small, round or oval patch, little if at all elevated, covered by a white or opalescent pellicle, and bounded by a faint red areola. It is usually multiple and symmetrically arranged on both sides of the fauces, the tonsils, the palate, and very infrequently the pharyngeal wall. In some cases there are no subjective symptoms, while in others the affected parts are extremely sensitive, and there may be some degree of constitutional disturbance.

Most cases yield to internal treatment, while others exhibit marked resistance or show a tendency to relapse. When healing is tardy, occasional stimulation, either by a solution of silver nitrate (30 gr. to the ounce) or by one of chromic acid (20 gr. to the ounce), will be of service. Objection to the prolonged local use of silver nitrate, at least in infants, is offered by Lennox Browne on the ground that permanent discoloration of the skin (argyria) may result, as well as for the reason that it favors a tendency to hyperplasia "already a sufficiently marked sequel of all specific ulcerations." While the latter is probably true of weak solutions, some authorities maintain that strong solutions (five per cent and upward) promote absorption rather than hyperplasia. A thorough course of mercury and careful elimination of all sources of local irritation in the food, as well as of that supplied by tobacco and alcohol, are most important.

A superficial ulceration occurs in the late secondary period in the form of irregular patches, especially on the tonsils. It shows a certain degree of bilateral symmetry, described by Hutchinson as "Dutch garden symmetry." It is very obstinate and prone to relapse, and is often quite painful and attended by offensive fœtor of the breath due to decomposition of tenacious secretion. It is not clear whether this lesion should be looked upon as an aggravated grade of mucous patch or as a superficial gummatous deposit.

In this connection reference may be made to the question of contagion. We have been accustomed to regard the late lesions as less dangerous and, in consequence, to relax somewhat in the use of measures to prevent communication of the disease. It is startling to note that recent observations indicate that the secretions of even the gummy tumor are capable of conveying infection. If this be true, there is obvious need of greater caution on the part of the surgeon in handling these patients as well as in permitting them to mingle indiscriminately with their fellows. The discovery of the bacillus of syphilis (Spirochæta pallida) in the late stages of the disease confirms this view.

The later ulcerations of syphilis are due to softening of gummatous infiltration. This infiltration may be diffuse (*en nappe*) or circumscribed (gummy tumor) in the mucous membrane or in the submucous tissues; in other words, it may be superficial or deep. The ravages of the latter are often very extensive. The process of formation of a gummy tumor is sometimes so insidious and painless that breaking down and destruction of tissue have been accomplished by the time the patient becomes aware of the existence of any trouble. This is signally true in the region of the palate (Fig. 015). On the other hand, a lesion on the posterior wall of the lower pharynx may seriously affect nutrition in consequence of the pain it causes and the obstacle it offers to swallowing. A gummy tumor is soft, elastic, and usually not very sensitive. It may be single or multiple. An ulcerating gumma has raised, undermined edges and a sloughy base. At first, it is symmetrical and excavated; later, as the edges break

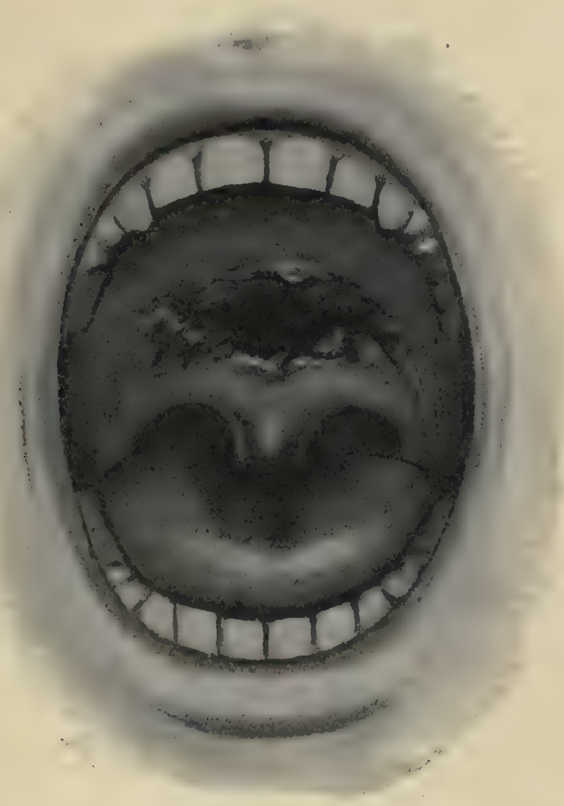

FIG. 417.—Ulcerating Gumma of the Soft Palate. (After De Blois.)

down and the ulcerative process invades contiguous parts, it becomes irregular. Some authorities, notably Bosworth, maintain that an apparent "progressive ulceration" is in reality a disintegration of preceding infiltration,—in other words, the ulceration is limited by the gummatous deposit. It is not easy to accept this idea when we see an ulcer encroaching upon a region where antecedent morbid changes cannot be detected. If the palate is involved, perforation into the rhinopharynx or nasal chambers may occur, in the latter case caries or necrosis of bone taking place. Several small adjacent gummata may coalesce and involve a wide area. Tabs and intervening spaces of sound tissue should never be sacrificed since they may be of use in repair. A similar dictum applies to interference with dead bone. It is far better to let Nature establish a line of demarcation than, by premature attempts at removal, to run the risk of damaging tissues that should be preserved. Indeed, the knife is but seldom indicated in syphilis. Many a softening gumma has been incised with the mistaken intention of evacuating a simple abscess.

In all therapeutics there is no more satisfactory experience than the prompt response of these lesions to internal medication. Hence the importance of early recognition. Rapid loading of the system with potassium iodide—on the first day, five drops of a saturated solution three times a day; on the second day, six drops at each dose; and so on, if necessary, until the limit of tolerance is reached—will usually show decided results in a few days. The drug is given in milk or Vichy water half an hour before or after meals, whichever is better tolerated. If cachexia is marked, and especially if early treatment has been inefficient, mercury and ferruginous tonics should be added. If necessary, pain may be mitigated by applications of cocaine, anæsthesin, or other analgesic; or, if moderate in degree, it may be soothed by insufflations of orthoform, or of iodoform in powder or ethereal solution. Otherwise no local treatment is called for, except the use of detergent washes and agents for correction of the fœtor due to sloughing or the presence of dead bone.

Retraction of scar tissue and adhesions between ulcerated surfaces may lead to such changes in the walls of the pharynx as to impair or even abolish function. When loss of tissue has been excessive, little can be done except to fill a void with an obturator or an artificial palate. If the margin of the velum is completely adherent to the posterior wall of the pharynx and the epipharynx is obliterated by adventitious bands, there is no satisfactory remedy. A naso-pharyngeal passage may be established, but it is found difficult or impossible to maintain it, contraction and closure being almost inevitable. In case of a comparatively narrow adhesion of the free border of the velum it is possible to secure permanent release, although the function of the palate is only imperfectly restored. Simple division does not give a lasting result, owing to a tendency to re-adhesion. Hooks of various shapes and material have been devised for the purpose of stretching and pulling forward the palate, but they must be used at short intervals and for an indefinite period of time. Among other procedures resorted to may be mentioned the following: loops of silver wire passed through the palate and fastened to the incisor teeth (Tilley); suturing the soft palate to the muco-periosteum of the hard palate (Spencer); rubber tubes passed through the nostrils and out of the mouth, their ends being fastened together over the upper lip (Abercrombie); White's self-retaining palate retractor (Creswell Baber); dental plate with tube to nasopharynx (McDougall) or obturator (Hamilton-Kollbrunner) attached.

A plan which has for its sole object the restoration of nasal breathing consists in inserting a permanent tube, attached to an obturator or plate—"*plaque* *à cheminée*"—at the posterior border of the hard palate. (Couetoux.) Some of these devices invovle retention in the air tract of a more or less cumbrous apparatus to which a large proportion of patients never can become accustomed.

The operation proposed by the late Dr. J. E. H. Nichols overcomes most of the difficulties in suitable cases. A stout needle, shaped like a staphylorrhaphy needle and armed with a coarse silk thread, is passed from below through the aperture in the velum (usually found near the median line), or, if one cannot be detected, through the substance of the velum, its point being brought down in a reverse direction as near as possible to the posterior and lateral walls of the pharynx. The needle is withdrawn leaving the thread, to one end of which is fastened a strand of heavy silk braid (No. 16). By traction on the free end of the thread the braid is gradually worked through and its ends are firmly tied together in the pharynx without strangulating the included part. After a week or two, or when it is certain that the canals occupied by the braid are scarred over, the braid is removed and the tissue intervening between the tracts through which it passed is divided with a right-angled knife. Great care must be taken to avoid disturbing the scar tissue lining the tracts. The operation may have to be repeated several times before adequate space is secured. The firm cicatrices at each end of the incision obviate re-adhesion, and the final result is satisfactory with reference to nasal breathing, and in some cases marked improvement in voice follows. Local anæsthesia is all-sufficient, except in certain hyperæsthetic subjects.

In many of these cases the general health is impaired and tonics and reconstituent measures are indicated. At this stage of the disease specific treatment may be ineffective, but it is a wise precaution, during and before beginning operative procedures, to have the patient under the influence of potassium iodide.

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IX. TUBERCULOSIS.

Tuberculosis of the pharynx may be primary or secondary. The primary form of the disease in the pharynx is so rare that the possibility of its occurrence is still discredited. The clinical experience of Lermoyez, Chappell, and others illustrates the risk of lighting up a latent tuberculosis by operative interference with an adenoid growth, while the numerous laboratory experiments of Dieulafoy tend to show the existence of unsuspected foci of tuberculosis in lymphoid tissue. Microscopic researches and animal inoculations made by Wright and

Park failed to prove the frequency of lymphoid tuberculosis. Their results were negative in twelve experiments and correspond closely with those of Ricardo Botey, who concludes that there does exist a rare form of tuberculous hypertrophy of the tonsil impossible to be distinguished on inspection from a simple hypertrophy and not attended by pulmonary or intestinal lesions. Later investigations by Wright of more than a hundred specimens of tonsils—fifty-one pharyngeal, fifty-four faucial, and sixteen lingual—confirmed his first conclusions, in no instance bacilli or typical giant cells being found. In spite of much negative testimony there is such a disease as primary tuberculosis of the pharynx, to be diagnosticated perhaps only by the microscope and inoculations, and not necessarily followed by general tuberculosis, owing to the fact that the cervical lymph nodes offer an impassable barrier to the bacilli. The infrequency of the disease in this locality may seem surprising in view of the prevalence of tuberculosis and of the fact, which appears now to be indisputable, that bacilli are capable of penetrating the unbroken epithelium of the mucosa. The presence of tubercle bacilli on the mucous membrane of individuals who remain perfectly healthy is beyond question. As a rule, they are promptly dislodged by the acts of mastication and deglutition, and the theory that the buccal secretions contain ingredients antagonistic to germs is reasonably supported.

In the primary form of pharyngeal tuberculosis the usual mode of infection is by direct inoculation through the inspired air or ingesta. In the secondary form the bacilli are conveyed by the blood current, or through the lymph channels, or possibly by the expectorated sputum from the lungs.

Prognosis.—In the primary disease the prognosis is good, provided the tuberculous deposit be circumscribed and superficial, and provided vigorous treatment be instituted. In the secondary form the pharyngeal manifestation must be looked upon as indicative of wide generalization of disease and therefore as an unfavorable development. This fact may be the basis for the opinion expressed by Bosworth that the nearer a tuberculous lesion approaches the external surface, the more virulent appear its phenomena.

Diagnosis.—In many cases the diagnosis of pharyngeal tuberculosis is very difficult. To differentiate it from syphilis a tentative course of specific treatment may be required. Even here are elements of error, since in certain cases temporary improvement under iodine occurs in tuberculosis, while on the other hand some cases of syphilis respond slowly to treatment. Moreover, the microscopic evidence is apt to be indecisive, since the scrapings and even the tissue itself of a typical tuberculous lesion may fail to show bacilli or giant cells. The question may be further obscured by the existence of mixed infection. After all, the clinical history and the discovery of characteristic lesions elsewhere must be our chief reliance. With malignant disease the danger of confusion is less, yet there lingers in the memory of the writer a case of extensive ulcer of the base of the tongue, supposed to be cancerous, in which that organ was amputated, the diagnosis of tuberculosis being established only after repeated and careful microscopic examinations.

Two forms of tuberculosis are recognized: one a diffuse miliary and the other a circumscribed papillary infiltration. In both there is a deposit of small round cells in the connective tissue and in both the blood-vessels are eventually involved (obliterative endarteritis followed by cheesy degeneration and ulceration). Giant cells and bacilli may or may not be found. In consequence of interference with the circulation by the cellular infiltration, or, as assumed by some, by a toxic vaso-constriction, the mucosa is anæmic. In certain cases the lesion appears in the shape of a series of fringe-like excrescences along the margins of the pillars (especially in primary cases). In the ulcerative stage the lesions may be multiple, from softening of isolated miliary granules. These possibly unite later to form a large ulcer with notched, eroded edges, and surrounded by a slightly red œdematous margin. In extremely rare cases perforation of the soft palate and even of the hard palate, establishing a direct opening from the mouth into the nasal chambers, has been noted. The success of attempts to describe a tuberculous ulcer is doubtful. One authority refers to it as being "lenticular in shape, with ill-defined, eaten out, and slightly raised margins, of a pale yellow color, and with faintly hyperæmic areola." On its shallow floor are seen "granulations or warty excrescences of pale pink color, covered with thin unhealthy pus." (Lennox Browne.) Another sees it flush with surrounding parts, its color similar to that of the adjacent mucosa and its surface concealed by ropy mucus. (Bosworth.) Variations in appearance and numerous errors in diagnosis force the conclusion that a "typical" tuberculous ulcer is the exception rather than the rule. In many cases the diagnosis must rest upon the history and the general symptoms.

Symptoms.—Pain often extending to the ear is sometimes extreme, but it is not invariable and is said to be less in cases complicated by syphilis. (R. Levy.) Odynphagia from this cause and dysphagia from interference with muscular action by infiltration may seriously affect nutrition. On the other hand, in some cases of even extensive ulceration pain is surprisingly slight. Aside from pain various paræsthesiæ (tickling, burning, a sensation of being scratched) are described. Otherwise the symptoms most complained of are those referable to the general condition or to some visceral lesion. Reflex cough, not dependent upon a pulmonary lesion, is a cause of annoyance. Sputa may be tinged with blood from this source, but free bleeding from a pharyngeal ulcer is not common. More or less œdema of adjacent parts, especially the uvula,—in which locality it presents a semi-solid character peculiar to tuberculosis,—is observed, and sooner or later the cervical lymph nodes become enlarged and sensitive. These lymph nodules remain quiescent indefinitely or soften and discharge through sinuses which close and reopen at intervals.

The opinion has recently been expressed by Wyatt Wingrave that many "tuberculous" lymph nodes are erroneously so called. A large number examined by him showed all the histological appearances of tubercle without the specific organism. Yet the absence of bacilli, or rather the failure to demonstrate them by the usual staining method, does not exclude tuberculosis in the face of presumptive clinical evidence, and any practice based on the dogma "no bacilli: no tuberculosis" is certainly dangerous.

The tone of the voice is not altered, unless the larynx be likewise affected, but its quality and resonance are impaired and the patient refrains from talking because of the discomfort or possible pain which the effort excites.

Treatment.—In a large proportion of cases of pharyngeal tuberculosis local treatment must be regarded as merely subsidiary. Only in primary cases is a definite expectation of cure from local treatment justified. The usual rules as to diet, hygiene, exercise, and general régime are of the first importance in secondary disease and hardly less so in primary, since the occurrence of the latter, as of the former, clearly shows that the resisting power of the individual is below the standard. This view by no means implies that local treatment is useless and should be abandoned. On the contrary, it is of the utmost service in suitable cases; by which term is meant those in which the pharyngeal lesion is accessible and in which developments elsewhere are not so far advanced that the patient's reparative powers are excessively reduced. Acute miliary tuberculosis, which is generally secondary and pursues an extremely rapid course, is beyond relief except as regards mitigation of the excruciating pain by which it is accompanied. The case put on record by Gouguenheim, in which the disease was confined to the tip of the uvula and was eradicated by amputation, should be regarded as unique. In desperate cases, radical interference being precluded, measures to control local irritability are plainly indicated. In order that proper nourishment be taken, the distressing pain in swallowing must be overcome. For this purpose the following drugs may be enumerated in the order of their safety, viz., orthoform, in powder or emulsion (Freudenthal); cocaine and its congeners; and, finally, codeine or morphine, both locally and internally. As to the last, no difference of opinion exists concerning its effect hypodermically, but its sedative power when applied locally is less obvious. In using these agents it becomes necessary to weigh the danger of a drug habit against the evils resulting from deficient nourishment and lack of sleep. They should be resorted to when food is refused on account of pain in swallowing and when rest is disturbed by cough and irritation in the fauces. The radical treatment of pharyngeal tuberculosis consists of thorough extirpation of the morbid deposit by means of a curette, followed by the application of lactic acid, which is to be rubbed into the denuded surface (practically the method recommended by Krause in tuberculosis of the larynx). The ulcer or infiltration is first cleansed with an alkaline solution or with enzymol (an excellent solvent of viscid purulent secretion), and the diseased tissues are excised with a sharp curette or double-cutting forceps. After bleeding has been checked, lactic acid in solution, of a strength varying from forty to one hundred per cent, is well rubbed in with a cotton applicator. As final measures the parts are insufflated with orthoform or with aristol, and the patient is forbidden to speak or eat for several hours, depending upon the degree of reaction. This process is repeated at weekly intervals until signs of repair and cicatrization are manifest. Pain and bleeding are minimized by applications of cocaine and adrenalin. In certain situations, as the tip of the uvula, the surface of the tonsil, or the margin of the epiglottis, the affected part may be ablated *en masse* with snare or guillotine. To most patients menthol in oily solution is grateful and it is even credited with antiseptic and healing properties. (Rosenberg.) Many other local remedies such as guaiacol, sulpho-ricinate of phenol (Ruault), parachloro-phenol (Simanowski), formalin (Solis-Cohen, R. Lake, O. J. Stein), and so on, have their adherents, but possess no decided advantages. Under favorable conditions a tuberculous ulcer may be healed, but it will not remain so, unless the general disease be controlled.

Notwithstanding discouragements and disasters in connection with the early use of Koch's tuberculin it is still employed for remedial as well as diagnostic purposes. The methods of preparation and administration have been so modified that it is believed to be free from risk. Although there is a wide difference of opinion among those experienced as to its efficacy, there is pretty general agreement that in advanced cases it is powerless. Phototherapy, by electric light or by sunlight, offers an interesting field for investigation. The experiments of Sorgo and others with sunlight in laryngeal tuberculosis are encouraging. A lesion of the pharynx might be expected to respond to treatment with at least equal promptness.

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X. LUPUS.

Lupus has been called a local, superficial, benign, or attenuated (Marty) tuberculosis. Whatever resemblance there may be in pathological findings, the contrast in clinical picture and course of these diseases is striking. The question of their identity, stoutly maintained by Demme, is still open and must remain so until inoculation of the tubercle bacillus is proved to cause lupus. More or less affirmative testimony has been offered by the laboratory as well as by the clinic, but there is as yet no satisfactory proof. Inoculation of the tissue of lupus has caused inflammatory reaction, but no true lupus. Clinical evidence also is lacking "unless we accept extremely careless statements." (Kaposi.) In the words of Jonathan Wright: "Tuberculosis is frequently, but not constantly, produced by the inoculation of lupus material; lupus itself has never been reproduced by inoculation." Lupus of the pharynx usually occurs by extension from the nose or the mouth, and is generally associated with a cutaneous manifestation. So many primary cases in the nose, pharynx, or larynx have been recorded since the initial one of lupus of the larynx, by von Ziemssen (1876), that involvement of the skin is no longer regarded as an essential antecedent.

The lesion consists of discrete masses of cellular infiltration in the submucous structures, which show a tendency to break down, ulcerate, and rapidly cicatrize. Giant cells and tubercle bacilli may be discovered, but the latter are generally absent or not demonstrable. Any part of the pharyngeal wall may be attacked. The structures affected may be widely destroyed and distorted by scars. The process is extremely slow and the prognosis is more favorable than in tuberculosis.

Lupus is met with in very young subjects,—according to Leloir, even in infancy,—and more often in females than in males. Instances of hereditary transmission are rare and not authentic.

Symptoms.—The course of the disease is so chronic and painless that often the lesion has covered considerable territory before the patient seeks relief. The voice is not affected or it becomes rough and low-pitched, even when the larynx itself is exempt. Nasal breathing is impeded in the later stages by cicatricial bands. Swallowing is rendered difficult by the infiltration and stiffness of the affected parts. On inspection the mucous membrane is seen to be dark-hued and granular, with here and there distinct, hard, yellowish, insensitive nodules, the size of a pin head or larger, which tend to ulcerate in a serpiginous way, or, according to Gottstein, may undergo absorption. In either case there results great deformity from cicatricial contraction. A tendency of the scars to break down is said to be pathognomonic. (Chiari.) Webs, bands, and adhesions of scar tissue are seen side by side with an active necrotic process; ulceration progresses and cicatrization follows. The latter may cause great distortion and interference with the functions of the nares and of the ears, as well as of the pharynx itself. The ulceration is never very deep as in syphilis, but in course of time the tonsils, the uvula, the velum, and the epiglottis may almost completely disappear. The cervical lymph nodes are sometimes enlarged. There is no constitutional disturbance of consequence.

Treatment.—The treatment is similar to that applied to tuberculosis, viz., ablation, or destruction of the morbid tissue by the galvano-cautery or by chemical caustics. Of caustics silver nitrate has been found effective in some cases. The electric cautery is more manageable and more thorough. Local applications of milder type are not of much avail. For the ulcerations good results are claimed by Braden Kyle from insufflation of five-per-cent pyoktanin in stearate of zinc. Lactic acid is popular with many, among them Shurly, who, in a case of lupoid laryngitis, had good success with its use followed by sprays of a strong solution of resorcin. He regards applications of resorcin or iodoform, combined with the use of the galvano-cautery, lactic acid, or chromic acid, as the most effective and safest mode of treatment. In cutaneous lupus electrolysis, the violet rays of light, and the Roentgen rays have been found efficacious by various observers, and they might be expected to work equally well on mucous membranes. Internally, the iodide of iron and arsenic in some form are useful.

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XI. BENIGN TUMORS.

New-growths in the pharynx are not very common, if we except those wart-like excrescences often seen on the velum or uvula. As a rule, these diminutive tumors do not exceed in size that of an ordinary pea, they remain stationary indefinitely, and are perfectly innocent. Rarely, in neurotic subjects, they seem to be the exciting cause of reflex cough or spasm of the larynx, and need to be removed. French's case in which nausea and vomiting were excited by a growth hanging from the uvula is exceptional, while the case of hystero-epilepsy in a boy of nineteen, described by Herzfelder, is without parallel.

Fibroma.—A pure fibroma of the pharynx is rather unusual, fibrous tissue being admixed, in the majority of cases, with other constituents. The tumor may be pedunculated or it may have a broad base of attachment. In the latter case, especially, it is apt to be quite vascular and it is therefore safer to undertake reduction by cauterization or by electrolysis rather than by excision. When the growth is pedunculated it may be removed with the cold wire snare.

The extraordinary vascularity of fibromata of the naso-pharynx has led Koenig to denominate them *fibro-angiomata.* Their blood-vessels are not only numerous, but thin-walled and fragile. They resemble malignant tumors in this respect as well as in their rapid growth and tendency to recur. The latter character is explained by the peculiar richness of this region in fibrous tissue, or by the fact that the sphenoidal sinus gives origin to or is invaded by the tumor. Under the latter circumstances radical extirpation is difficult and dangerous. In some of these cases sarcomatous elements are actually found at certain points,—a discovery which of course throws the case into the class of malignant disease.

Two interesting cases, among others, are mentioned by Sir Morell Mackenzie in his manual—one apparently a fibroma, and the other resembling a mucous polyp of the nose, each pedunculated and supposedly attached to the wall of the pharynx.

Lipoma.—A few cases of lipoma are on record. They are sometimes pedunculated, as in Holt's oft-quoted case of lipoma of the epiglottis, which completely filled the lower pharynx and when forced upward over the *rima glottidis* threatened suffocation. A lipoma in this region is soft and elastic, somewhat resembling an abscess, from which it may be differentiated by puncture or incision. Pyrexia and the usual signs of suppuration are absent and the tumor is insensitive and painless.

Angioma.—The vascularity of angioma, one of the rarest of neoplasms, renders attempts at removal with the knife unwise. It seems hardly proper, as is done by some writers, to include under this title varicose veins (the plexus of Cruveilhier) and those small vascular protuberances which are sometimes seen, especially in the aged, on the posterior pharyngeal wall and in the hyoid fossa. The latter may bleed rather freely when eroded, but otherwise neither has any significance. The dark purplish color and uneven contour of an angioma is distinctive, but it may be disguised by inclusion in its substance of a large proportion of fibrous tissue. If interference is demanded, electrolysis and the use of the galvanocautery are the methods of choice.

Papilloma.—Papilloma is the most frequent of all benign new-growths and is seen at almost any part of the pharyngeal wall, as well as springing from the surface of the tonsil. Among more than thirty thousand cases seen by Moritz Schmidt in the course of ten years there were forty-nine benign growths of the pharynx, and forty of these were papillomata. Unusual interest attaches to this neoplasm from the fact that the diagnosis is often difficult, several cases supposed to be innocent having proved to be epithelioma. It occurs as an irregular lobulated mass, usually pendulous and pedunculated, without sign of irritation or infiltration, but sometimes showing a tendency to rapid growth and recurrence after removal.

Chondroma and Adenoma.—A few cases of cartilaginous tumor and several of adenoma have been met with in the pharynx. Tumors of the latter variety are prone to develop from the submucous glands on the anterior surface of the soft palate. (Schech.) Slow growth is a characteristic feature of these tumors, especially as distinguished from sarcoma, which they somewhat resemble in other respects. In a case described by Escat six years elapsed before the patient experienced any special inconvenience.

Chondroma has been seen only in the nasopharynx. Adenoma may appear in cystic form and more especially in combination with other tissues, particularly fibrous and sarcomatous.

Cystoma.—Cystoma usually is due to occlusion of a gland duct and is therefore a retention cyst. When occurring in lymphoid tissue it is believed to be a result of fatty degeneration. The epiglottis is a favorite site. In the vault of the pharynx occurs so-called *Tornwaldt's disease,* or cyst of the pharyngeal bursa. Occasionally an old mucous polyp of the naris, that projects into the naso-pharynx, undergoes cystic degeneration. The nature of these conditions is usually disclosed by the mirror, or, if not, by palpation, although the precise site from which the cyst springs may not be easy to determine. Unless the contents of the cyst are turbid with pus or débris, or its walls very thick, the tumor appears smooth, glistening, and translucent, and to the touch it is elastic and fluctuating. It often happens that the cyst is ruptured during an examination with the finger, when the tumor disappears, leaving only its shrivelled walls. The remnants may be removed if necessary with forceps or curette.

Symptoms.—The disturbance created by these benign neoplasms depends upon their situation and proportions. Interference with breathing, with hearing, with swallowing, or with speech would not be expected until a late stage. Various unpleasant sensations aside from pain, catarrhal irritation, certain reflex disorders, and in some cases hemorrhage or blood-stained secretions, are among the most prominent symptoms. The last-mentioned phenomenon is seldom met with except in angioma and fibroma of the nasopharynx. The latter is also attended by pain, as nerve trunks are compressed by steady growth of the tumor. In the course of time it causes a characteristic facial deformity (frog-face) by expansion of the bones from pressure, and it finally results fatally from meningeal irritation or invasion of the cerebral fossa. When it is fully developed, the presence of the tumor is readily identified. In the early stages the rhinoscopic picture is not sufficiently clear, but digital examination permits us to recognize the extreme woody hardness of the tumor, its immobility, and its smooth symmetrical contour. Rough handling is, moreover, apt to provoke bleeding difficult to control. Perhaps the most important source of error—one, fortunately, which is very rare—is a combination of adenoids with fibroma, whereby the actual state of things is completely concealed. These fibrous growths usually occur in the young (one at the eighth year recorded by Escat) and have a fatal result within a few years, unless the patient survive to maturity, when the prospect of ultimate recovery from arrest and atrophy of the tumor is somewhat better. (Mikulicz.)

Treatment.—When the pedicle is attenuated and within reach, it may be twisted with forceps or divided with scissors or the knife. The wire snare, hot or cold, is useful in a case of this kind. If the tumor is large and has a broad base, it is often necessary to decide between an internal operation and an external pharyngotomy, whether a preliminary tracheotomy is advisable or unnecessary, and whether to choose the knife or a bloodless operation. A cyst may usually be disposed of by simple incision and curetting its interior. In doubtful cases electrolysis, the galvano-cautery, and injection of the mass with corrosive agents have all been employed with success. Interstitial injection of an acid, such as monochloracetic, trichloracetic, or lactic, should be practised with the utmost caution, since great discomfort if not danger may attend diffusion of the fluid.

It is considered unwise to use the cautery over a great extent of surface owing to the risk of septic absorption. Surface cauterization with a broad electrode, multiple punctures of the body of the tumor in the hope of destroying its vitality, and finally removal of the growth *en masse* with the hot *écraseur*, provided its base can be encircled, have all been recommended. The objections to these methods are the difficulty of avoiding damage to adjacent parts by diffusion of heat, and, when the vault of the pharynx is the field of the operation, the danger of violent inflammatory reaction with transmission to the meninges. In some instances a tumor has been found to be in a measure encapsulated, and enucleation, after division of its investing membrane, has been effected with ease. This experience has been met with especially in connection with adenoma. The use of the finger in avulsion of tumors is referred to by Ingals in discussing the treatment of fibrous tumors of the nasopharynx. It is applicable to a very small proportion of encapsulated or pedunculated neoplasms; the majority are sessile and diffuse, or send prolongations in various directions, thus necessitating a tedious dissection.

When electrolysis is used, the needle connected with the negative pole is inserted in the tumor, while the positive electrode is applied to the nape of the neck (monopolar), or needles connected with each pole may be passed into the growth (bipolar). It is desirable to use a strong current (from forty to sixty milliampères) and to continue it for ten or fifteen minutes. (E. F. Ingals.) According to Lermoyez, as high as eighty milliampères may be used without the least danger. The precaution should be taken to reduce the current before withdrawal of the needles. In an operative procedure so near the nerve centres more or less cerebral disturbance may be observed unless care be taken as to volume and duration of current. The pain is considerable and moderate general anæsthesia may be required. The duration of sittings and the length of the interval between them depend upon the results produced. In a successful case of recurrent fibroma reported by R. P. Lincoln sixteen applications, each occupying from twelve to twenty minutes, were made at intervals of from four to six days. There seems to be some uncertainty as to whether the effects by this method are not in part caustic as well as electrolytic.

In weighing the relative merits of an external and an internal operation, in the case of a fibrous polyp of the naso-pharynx, the size of the tumor and its attachments should be determined. The latter is sometimes impossible. In spite of this fact and whatever the volume of the tumor, some operators express strong preference for removal by endonasal rather than external operation. (Doyen.) If necessary, the turbinates may be reduced by preliminary conchectomy, the postnasal space being thus exposed. In certain cases satisfactory access might be given by way of the maxillary sinus and the outer wall of the nose, after the Jansen method in sphenoidal empyema. On the assumption that the chief source of hemorrhage in nasopharyngeal fibroma is the vascular capsule, A. J. Brady advocates rapid separation of the tumor from its bony attachments by means of a blunt Langenbeck periosteal elevator until its base is released. It is then seized with vulsellum forceps passed through the mouth and forcibly wrenched from its bed. The free bleeding that always occurs at this juncture may be controlled by firm pressure. A preliminary tracheotomy is not considered essential. The elevator is passed through the anterior naris and guided by a finger in the postnasal space. More room may be gained for manipulations by external incisions made for the purpose of raising the wing of the nose and removing a portion of the nasal process of the superior maxilla. Thus it is claimed to be possible to dispense with more formidable and mutilating operations. Division or resection of the palate (Nélaton), temporary resection of the nose (Ollier), and resection of the upper jaw, temporary or permanent (Syme), are called for only in tumors of extraordinary size. With the patient in Rose's position there is no need in most cases of further precautions—as, for example, by the use of Doyen's pharyngeal tube, a tampon, or a tracheal cannula—against the entrance of blood into the lower air tract. Bleeding, while free, can usually be checked by packing the vault with a temporary gauze tampon.

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XII. MALIGNANT DISEASE.

The varieties of malignant disease occurring in the pharynx are carcinoma and sarcoma. Of the former, epithelioma is the most common, although cases of scirrhus and encephaloid are mentioned by some writers. The early dissemination of the disease renders the prognosis unfavorable and necessitates an operation involving wide mutilation. For these reasons interference, except in the earliest stages, is discountenanced by some. Nevertheless, very extensive ablation of affected parts has been done by more radical operators with surprisingly little shock and ultimate functional derangement. In excision of disease from this situation the injunction to keep far away from suspected tissues is especially urgent. Of sarcomata, the small-celled variety and lymphosarcoma are the most common. Melanotic, alveolar, and myxosarcoma, and in fact nearly all kinds, have been observed. The abundance of lymphoid tissue in the pharynx would lead one to expect frequent occurrence of lymphoma. It is found in the form of lymphadenoma, or lymphosarcoma, both being practically malignant in nature. The former is sometimes associated with a general adenopathy, the cervical lymph nodes being affected first and to the greatest degree, and with certain changes in the spleen (hyperplasia) and in the blood (leucocytosis) constituting a pseudoleukæmia or Hodgkin's disease. (H. T. Butlin.)

A differential diagnosis is often impossible without excision and histological examination of one or more affected nodes. As to tuberculosis, attention is drawn to the following points which distinguish it from lymphadenoma (H. Senator):—The development of tuberculous adenitis is rare after the twenty-fifth year. The affected nodes are painful and tender and other organs are usually involved. Pyrexia is generally present. Finally, tuberculous nodes become adherent, undergo caseation, and, if superficial, rupture through the skin. The last is a rather late episode, and indeed may not occur at all in what is known as the indurative form of tuberculosis, while, on the other hand, it is sometimes observed in lymphosarcoma. In many cases, therefore, it is difficult to reach a positive conclusion. One or both tonsils may be affected. The development of the disease is rapid, ulceration and hemorrhages take place, dysphagia and dyspnœa ensue from enlargement and diffusion of the tumor in the fauces, and a fatal termination follows. Surgically there is nothing to be done, except in a palliative way, for temporary relief of the pharyngeal obstruction. Internally, it is customary to give arsenic in some form, apparently without any substantial reason or result.

The causes of malignant disease are as much a mystery here as elsewhere. Prolonged local irritation in carcinoma and trauma in sarcoma are generally looked for as exciting causes. The disease may be primary or may extend to the pharynx from adjacent parts. Carcinoma occurs late in life, sarcoma at any period. Involvement of the lymph nodes appears early in the former.

Symptoms.—The early symptoms are often very obscure. About the first to attract attention, if the lesion is in the food tract, is pain in swallowing. Spontaneous pain occurs later when deep infiltration involves nerve trunks or the surface is eroded by ulceration. The pain is often lancinating and darts toward the ear of the affected side, especially when the tonsillar region is involved. At an early period the flow of saliva is increased, and when the tissues begin to break down the breath becomes fœtid. The cervical lymph nodes become enlarged and indurated and a condition of cachexia develops. Attacks of hemorrhage may be severe and frequent, especially if the progress of the disease is rapid. All the foregoing symptoms are more tardy and less pronounced with sarcoma than with carcinoma. In fact, in sarcoma the symptoms may be almost exclusively those caused by mechanical obstruction, the ulceration is never deep and ragged as it often is in carcinoma, and cachexia if present is less marked. In carcinoma the submaxillary and cervical lymph nodes are usually enlarged, but absence of adenopathy does not exclude malignancy. Headache is often an early symptom and is very intense. Aural complications may arise in the form of otalgia, impaired hearing, or suppurative otitis. An ichorous nasal and postnasal discharge accompanies ulceration. Ankylosis of the jaw may result from invasion of the temporo-maxillary joint or from muscular infiltration. Hemorrhage may amount to no more than a mere staining of secretions or it may be alarmingly free, in the latter case being due to erosion of an artery. At the outset a cancer may have a fungous or wart-like appearance like that presented by a papilloma. Later, in the stage of infiltration, the parts are tense, indurated, and sensitive to touch. When ulceration begins it is often impossible to differentiate the condition from syphilis without a course of specific treatment. The ulcer is usually very ragged, with hard, elevated, undermined margins, and covered with sloughy-looking débris. In many of its features the ulcer resembles an ulcerating gumma. The microscope may be called upon to confirm the diagnosis in carcinoma, but in sarcoma its testimony is less reliable.

In sarcoma the lymph nodes are affected at a later period, seldom if ever before ulceration begins. The lesion itself is less painful and less sensitive. Ulceration is more superficial and the tendency to form vegetations is less marked than in epithelioma and does not manifest itself so early. The disease advances more slowly and may remain stationary for a considerable time. It appears as a smooth elastic tumor, or as a diffuse infiltration which is sometimes mistaken for syphilis. When involving the tonsil, it may be at first regarded as a simple hypertrophy, whereas any unilateral tonsillar enlargement, at least in adults, should be looked upon with suspicion. As to syphilis, careful inquiry usually discovers some corroborative symptoms and marked improvement under mixed treatment dispels all doubt.

Treatment.—In discussing the question of treatment we have to consider, as suggested by Watson Williams, (1) the possibility of complete eradication, (2) the risks involved, (3) the functional results, and (4) the chances of recurrence. The first and fourth points are inseparable, since, if removal be incomplete, recurrence is certain. As to the other two, in operations of this kind as in all equally formidable operations, the views and wishes of the patient, who has been thoroughly informed of the probabilities, should be taken into account. According to Cheyne, disease involving the upper part of the tonsil and the adjacent palate offers the most favorable outlook for surgical interference. The lower in the pharynx the disease extends, the worse the prognosis. When surgical results are disappointing, we naturally turn to other resources.

In certain cases of sarcoma injection of Coley's fluid * seems to have had some effect, but, as a rule, it has not been successful, while in carcinoma it is admittedly valueless. Hypodermic injections of "trypsin," an enzyme extracted from the pancreas and vaunted with enthusiasm by John Beard, of Edinburgh, will doubtless be tried in cancer of the pharynx, as it has been in that of the larynx. (C. C. Rice.) Unfortunately, the evidence is not yet all in, and the alleged cures were effected in cases in which the diagnosis was, to say the least, doubtful. A similar conclusion applies to the inoculation of cultures of Doyen's *Micrococcus neoformans.* Of five cases thus treated by Spicer and Wright, one showed "marvellous" improvement, another "marked signs of improvement"; one was stationary, and two were fatal. In a case of spheroidal-celled carcinoma in which the most striking results were observed, favorable changes, both general and local, began at once, progressed for five or six weeks, and were then arrested. No other treatment was followed at the same time, except a simple antiseptic wash, although potassium iodide in fifteen-grain doses three times a day had been given for a week previously without effect. Electrolysis and electric cataphoresis have their supporters. Radium and the Roentgen ray have been used with absolutely contradictory results as regards curative power. Opinion as to their capacity to mitigate pain seems to be more nearly unanimous. The galvano-cautery is available only in comparatively superficial and circumscribed disease. When the knife is resorted to, a choice must be made between an operation through the mouth or nose and an external cut. The former is practically reserved for disease limited in extent and occupying the upper or middle pharynx, and is wisely preceded by a tracheotomy, as hemorrhage is generally extreme. A tumor of the nasopharynx is often properly exposed only after division of the palate or resection of the upper jaw. Similarly, the lower jaw may be divided and turned aside in order to give easier approach to disease involving the tonsil or the lateral wall of the oropharynx. An extensive lateral pharyngotomy is called for, if ever, only in cases of advanced disease in which the question of operative interference of any kind is debatable. Several cases of sarcoma in an early stage are on record in which generalization of the disease has been prevented by a firm investing membrane from which it was possible to shell out the encapsulated tumor. The "starvation method" of dealing with

* Coley's fluid is described in detail in American Journal of the Medical Sciences, vol. cxxxi., p. 381, March, 1906. It contains the mixed toxins of the streptococcus of erysipelas and the bacillus prodigiosus; the mixture being prepared according to the formula of Dr. B. H. Buxton.

In Annals of Surgery, vol. 45, p. 357, March, 1907, Dr. Coley says that Dr. Martha Tracy, of the Huntington Cancer Research Fund, under Dr. Buxton's direction, has lately made an improved preparation of mixed toxins. The method formerly consisted in growing the bacillus prodigiosus in the same bouillon with the streptococcus of erysipelas. She has now grown the prodigiosus separately, sterilized in just sufficient heat to destroy the bacilli, reducing the growth to a dry powder, and then adding a definite amount by weight to each ounce of the streptococcus broth. It is a more stable and powerful preparation and has shown a distinct improvement in results over the older preparation.

malignant disease practised by R. H. M. Dawbarn, the blood supply of the affected region being cut off by ligation of the afferent vessels, may be feasible as an inhibiting measure in suitable cases. In this connection it is interesting to note the case of Dubreuil, quoted by Bosworth, of adenoma, in which the common, internal and external carotids, and the superior thyroid artery were ligated in turn with the result that atrophy of the growth took place. As a general principle it may be said that sarcoma is less malignant than carcinoma, and the prognosis from operative interference in the former is relatively better.

The dictum that malignant disease is inevitably fatal and that whenever recovery takes place the diagnosis must have been faulty, is not true. Several recorded cases attest the fact of spontaneous cure.

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XIII. PHARYNGOTOMY.

In a condition demanding approach to the cavity of the pharynx by external operation a transverse incision may be made above the hyoid bone (suprahyoid pharyngotomy), or in the thyro-hyoid space (subhyoid pharyngotomy), or a longitudinal cut may be made in the side of the neck along the anterior border of the sterno-mastoid muscle (lateral pharyngotomy). The last is regarded as safest and as giving freer access. A transverse incision, especially in the thyrohyoid space, exposes the superior laryngeal nerves to damage with consequent anæsthesia of the larynx and its familiar dangers. Temporary resection of the hyoid bone, with the idea of gaining more space for operative work, has recently been suggested. (Broeckaert.)

In only a very small percentage of impacted foreign bodies is pharyngotomy indicated, and in most cases of cicatricial stenosis dilatation through the mouth is feasible. Hence this operation is practically reserved for that limited class of cases in which the pharynx is the seat of a tumor or a foreign body which is not otherwise removable. In tumors of the tonsil, especially those of a malignant nature, and in disease extending high in the pharynx, it is often necessary to do a resection of the lower jaw, permanent (Mikulicz) or temporary (Langenbeck), in order to get a satisfactory exposure of the affected parts. It is important that the primary incision should be of generous length, in some cases from the mastoid to the level of the thyroid or even cricoid cartilage. In malignant disease, particularly, opportunity is thus given to detect and remove infected lymph nodes. The skin, platysma, and superficial fascia having been divided, great care should be exercised to avoid injury to the large blood-vessels and nerve trunks lying in the cervical triangle. When the wall of the pharynx has been reached, it is pushed into the wound and made tense by means of a pharyngeal sound, upon which it is incised. Through the buttonhole thus made the finger is inserted and used as a guide for extending the cut. By some operators a preliminary tracheotomy is considered unnecessary. It is certainly a great advantage to dispense with it, and this may safely be done if the patient is in proper position and care be taken to secure bleeding points as the operation progresses. Others not only tracheotomize but also tie the carotid as a precautionary measure. Various modifications of the incision are made with a view of facilitating access to some special region. For example, a transverse cut along the body of the inferior maxilla, connecting with the Mikulicz incision along the sterno-mastoid, gives more room for resection of the jaw and for reaching the tonsil. (Cheever.) The horizontal incision may extend from the angle of the mouth across the angle of the jaw to the anterior border of the sterno-mastoid (Kuester) and thence downward (Polaillon), in either case the ramus of the jaw being resected. In tumors limited to the tonsillar region excellent exposure is obtained by a semicircular incision beginning in front of the lobe of the ear and curving downward and forward to the middle of the lower jaw. (Polaillon.) An extensive incision from the buccal commissure curving downward to the level of the hyoid bone and ending at the mastoid apophysis, combined with division and reflection of the jaw, lays the pharynx wide open. (Kroenlein.) Whether the cervical wound should be completely closed or not, depends on the extent of the operation and the amount of tissue sacrificed. If it seem best to pack the wound in part, there is some danger that a fistula will result which will require subsequent treatment. In after-treatment the chief problem is that of providing nutrition without risk of infecting the wound. This may be accomplished by rectal feeding, by passing a feeding tube through the nose and beyond the site of operation, or, in extreme cases, by performing a preliminary gastrostomy. (See also the article on Surgery of the Neck in Vol. VI.)

SURGICAL DISEASES AND WOUNDS OF THE LARYNX AND TRACHEA.

By JAMES E. NEWCOMB, M.D., New York City.

I. ANOMALIES AND MALFORMATIONS.—DISLOCATIONS AND FRACTURES.—CUT-THROAT.—GUNSHOT WOUNDS.—LARYNGOCELE. —PERSISTENT THYROGLOSSAL DUCT.

Anomalies and Malformations.—No classification at all complete can be made of malformations of the larynx. All sorts of stenotic deformities may result from ulcerations due to diphtheria and other infective processes and from injuries, particularly attempts at suicide by cutting the throat. It is not at all uncommon to find the rima glottidis not in the exact median line of the body, but this deviation from the normal gives no symptoms whatever. Occasionally the two arytenoids are not in exactly symmetrical positions, one being a little behind the other, so that in attempted phonation the two seem to cross. This rarely causes any interference with breathing, but when it does the voice is not entirely clear. Fein, of Vienna, collected some years ago about a dozen cases of congenital membrane in the cavity of the larynx, adding the record of one personal case. A few similar instances have been reported since his monograph appeared. In a case reported by Hueter, a membrane was found on autopsy in a man dying of heart failure, his antecedent history being unknown. In this case the membrane rested on, or was attached to, the epiglottis and completely occluded the anterior portion of the larynx. Some thirteen years ago Calman reported a remarkable case in which the epiglottis was furrowed anteriorly by deep grooves that divided the organ into four leaves, partly cartilaginous and partly of connective-tissue formation. The ary-epiglottic ligaments were absent, and there were accompanying deformities of the tongue and hyoid bone.

The membranous formations above referred to appear in countless shapes and various situations. Most of them affect the anterior rather than the posterior part of the laryngeal box. Most of them also are deceptive, in the laryngeal image, as to their vertical thickness. They appear to be thin webs, but many, especially those of a congenital character, extend through the entire depth of the organ, becoming thinner as they descend. This is one reason why their removal is often difficult. When the larynx is first formed it is completely impervious, but, as development proceeds, a vertical channel gradually appears. These congenital cases are to be regarded as instances of incomplete channel formation.

Many of these cases give no symptoms whatever, and the condition is discovered accidentally. If the condition causes trouble, it is obviously in the direction of interference with laryngeal function, the milder forms being characterized by vocal impairment and the severer ones by disturbances of the respiratory function. Each individual case suggests its own treatment.

Dislocations and Fractures.—Fractures may result from falls, blows, sudden compression, etc., and are naturally more common in later life because at that period the cartilages are in an ossified condition. In 1881 Durham reported that the relative frequency with which the different laryngeal cartilages are involved is about as follows:—Out of a total of 62 cases of fracture of the larynx the thyroid was the part injured in 24, the cricoid in 11, and both of these cartilages in 9; in the remaining 18 cases there were various combinations of the thyroid and cricoid with other cartilages. In the literature, from 1895 to 1905 inclusive, we have found reports of 23 cases of fracture of the larynx. Of these the thyroid alone was involved in 12, the cricoid in 3, both in 1, both with the upper tracheal rings in 1, the thyroid cartilage and the hyoid bone in 1, the arytenoid in 1, the left half of the larynx in 1, and in the remainder the facts desired were not stated. When the cricoid is the part fractured the soft parts are almost always involved, while in the case of the thyroid the cartilage alone may bear the brunt of the injury. Gradenigo has reported one case in which there was habitual subluxation of the arytenoid.

Symptoms.—It is sometimes difficult, upon a first examination, to distinguish a given case of dislocation from one of fracture. The direction from which the exciting cause has acted determines the contour of the parts. Lateral compression naturally forces the thyroid forward, while a force acting from the front will tend to flatten it. There is more or less swelling, and palpation may reveal crepitus. Emphysema is a frequent occurrence. Blood or frothy, blood-tinged mucus may be expectorated. The voice is aphonic, cough is present, there is more or less dyspnœa, and, according to the seriousness of the injury inflicted, the degree of prostration will be insignificant or severe (amounting in some cases to syncope). If laryngeal examination is possible, there will be found more or less distortion of the laryngeal image. The ventricular bands are swollen, and often a prominence is noted in the region of the pyriform sinuses. Later dangers are suppuration and septic pneumonia.

Prognosis.—The prognosis depends directly on the site and the amount of the injury inflicted and on the possible perforation of the mucosa. The latter accident naturally favors septic absorption. An injury involving the cricoid, particularly if it be severe enough to cause comminution of the cartilage, is manifestly more serious than one in which the thyroid is simply split. Moreover, as a general rule, injuries of the cricoid, as already stated, seriously compromise the soft parts. Referring again to Durham's figures, we may state that there were 12 recoveries out of his 62 cases. Of these the thyroid alone was involved in 6, the thyroid and hyoid bone in 2, and in the remainder the desired data were not given. The total mortality, therefore, was 80 per cent, which closely agrees with the figures of Albert, Fisher (78 per cent, in 71 cases), Kemper (80 per cent), and Guert (70 per cent, in 68 cases). The similarity of these figures strongly suggests that they are based on practically the same cases. On the other hand, Harris (1895) was able to collate 30 cases (including one of his own) in which the mortality was only 30 per cent. In the 23 cases which we collated (see above) the results were as follows: 2 of thyroid fracture died while 8 recovered; the result was unknown in 2 cases; the arytenoid case recovered; of the 3 cricoid cases 2 died and one recovered. (The earlier authorities all agree in stating that cricoid fractures invariably result fatally, but this is not true.) In the case of fracture of the thyroid cartilage and hyoid bone the patient died, while in that of fracture of both thyroid and cricoid cartilages the patient recovered. It is probable that the larger mortality dates back to the earlier times when surgeons were less venturesome in intervening in these injuries. The future will probably show a still lower mortality. The figures of our own collated cases closely approximate those given by Harris. Of course, fractures of the larynx will always be classed as serious injuries, and intervention, to be of avail, must be undertaken immediately. In one or two instances it has been possible to demonstrate a fracture of the larynx in patients who presented no dyspnœa and who had only a slight hoarseness.

Treatment.—The patient should be put to bed as soon as possible; his shoulders should be raised; and ice compresses or the cold Leiter coil should be applied over the region of the larynx. If there is much contusion, leeches should be applied to the part. The urgent question is as to the necessity of tracheotomy. A prophylactic tracheotomy may be considered as indicated in the following conditions:—(1) in a continuous wound of the laryngo-tracheal mucosa; (2) in transverse or oblique and in multiple or comminuted fractures; (3) in fracture of the cricoid; (4) when a fracture is combined with subglottic or tracheal injuries; and (5) in impending suffocation from whatever local cause. The operation is not usually necessary in the simple cases and in those of vertical fracture of the thyroid. In the simpler cases it will be sufficient to mould the parts *very gently* into a normal contour, and then to retain them in this position by padding and strapping. Feeding should be by enema. The danger signal is dyspnœa, and, as soon as it appears, the only safe course is to insert a tracheotomy tube. Sometimes one may perform intubation, the tube serving both as a channel through which air may pass and as a splint around which the parts may heal. Subsequent cicatrices must be dealt with as they arise.

Occasionally one finds, entirely apart from any known trauma, a dislocation of the inferior cornu of the thyroid forward from its cricoid articulation. The accident may happen on either side; it may also recur frequently or only at long intervals. It generally causes intense pain, but is really not dangerous. Examination reveals, at the inner side of the sterno-mastoid muscle, a slight prominence at the level of the lower border of the thyroid cartilage. A predisposing cause of this accident is a loose capsule at this joint, and the exciting causes are contraction of the sterno-thyroid and crico-thyroid muscles in the acts of deep inspiration and yawning, especially in the recumbent position when the act is incomplete. Downward and backward pressure will, as a rule, restore the parts to their normal relations, often with a distinct click. A few attempts at swallowing will often be equally successful.*

Cut-Throat.—This accident is generally the outcome of suicidal intent. Often the skin alone is divided, or the subjacent muscle may be severed at the same time; and, while the bleeding may be profuse for a short period, the injury is in reality trivial, merely requiring hæmostasis, suturing, and dressing, with the chin approximated to the neck. Deeper wounds may involve the air and food passages, and insane people have cut clear through to the spine. The carotids and jugulars generally escape injury, although section of some of their larger branches is not uncommon. (For more detailed information regarding this subject the reader is referred to the article on Surgery of the Neck, in Vol. VI.)

Gunshot Wounds.—Gunshot wounds of the larynx and trachea are rare in civil practice and comparatively infrequent in warfare. For example, in the United States Civil War such wounds of the larynx and trachea formed only 0.035 per cent of all wounds treated, and in the Franco-German War they constituted a little less than 0.06 per cent of the total.

Mechanically considered, they are cases of fracture more or less complicated. There may be a simple perforation of the thyroid cartilage, a laceration of the vocal cords and epiglottis, or an extensive comminution of the cartilages and soft parts, a portion of which may be gouged out. The missile may injure large vessels, may be found in the larynx, and may sometimes become splintered so that a portion of it makes a clean, knife-like cut. In addition to the symptoms found in cut-throats, there may be emphysema of the soft parts. Healing is by fibrous tissue, which in time becomes cartilaginous or ossified.

For information with regard to the treatment the reader is referred to the article on Surgery of the Neck, in Volume VI.

Burns and Scalds of the Larynx.—Accidents of this nature do not seem to be as common in this country as in England. The frequent practice among the poor, in the latter country, of feeding children out of the spout of a teapot leads the child to experiment with the spouts of vessels containing boiling water, as a result of which the pharynx and laryngeal vestibule become œdematous and inflamed. A similar result may follow the ingestion, either by accident or with

* Harris, in Phil. Med. News, Feb. 23d, 1895; Hoffman, in Centralblatt f. Laryngol., 1902, p. 292; Scheff, in Centralbl. f. Lar., 1898, p. 56.

suicidal intent, of corrosive fluids of all sorts. Some cases result from the inhalation of flames.

Symptoms.—These are of speedy and almost immediate onset. The small rima glottidis of the child is quickly occluded, and, unless immediate relief is at hand, a fatal result ensues. Examination of the tongue, palate, and fauces reveals swelling and vesication. Swallowing is difficult and painful. The voice becomes weak, dyspnœa ensues, and soon there is a spasmodic croupy cough with stridulous breathing. Spasmodic dyspnœa is soon added. Such attacks are of the gravest import, as any one of them may prove fatal.

Treatment.—Treatment will depend on the gravity of the situation. Some of the milder cases are relieved by rest in a warm bed and inhalations of warm, moist air. Hot fomentations may be made to the neck. In some instances the laryngeal symptoms are at no time severe, and the patient is out of all danger at the end of three or four days. Such cases should be carefully watched, however, as the well-known English surgeon, Mr. Thomas Bryant, records notes of the case of a child whose symptoms were so slight as to cause no anxiety, but who succumbed to a spasm two and a half hours after the accident.

In the severer cases, and in fact in every case with progressive symptoms and spasmodic breathing, the only safety lies in an early tracheotomy. It is not prudent to wait. The longer the operation is deferred the more engorged the lungs become with blood and the greater predisposition there is to inflammation in these structures. Bryant's statistics show 5 recoveries out of 9 tracheotomies, and Durham's only 5 recoveries out of 28. Scarification of the epiglottis and œdematous structures with the laryngeal lancet may give some relief. A sharp tenaculum will answer if a lancet is not at hand. Blisters and leeches have been applied to the neck. Laryngotomy is not indicated, as the incision will have to be made too near the site of the lesion. Purely medical measures are of doubtful efficacy. Calomel has been given in doses of from two to three grains hourly until characteristic stools are produced. Antimonial wine has been administered in doses of a few drops every fifteen minutes. It is undoubtedly the most valuable internal remedy. Locally, we may spray the parts with a solution of adrenalin chloride (1:2,000).

Laryngocele.—Under this title are included those gaseous tumors of the neck which have their origin in some part of the larynx proper. Cases of both pharyngocele and tracheocele present the same general appearances and call for the same general treatment.

By "laryngocele" is meant a sac-like tumor which is located at the level of the larynx or in its vicinity, and which either still communicates with the laryngeal cavity or did so at the time of its formation. Hence we have two main divisions of this class of tumors:—I. those occurring without any solution of continuity of the laryngeal walls, and II. those which are consecutive to such solution of continuity.

Under I. we may have (*a*) tumors occurring under normal anatomical relations and (*b*) those occurring under abnormal relations. The latter are generally of congenital origin. Abnormal pouches, such as are known to exist in certain tribes of monkeys, are occasionally found.

(*a*) The air pocket is here formed at the expense of the membranous portions of the larynx, and becomes distended under the influence of strong intralaryngeal pressure. It manifests itself after repeated vocal efforts. It is unilateral or bilateral, bosselated, and disappears during repose and methodical compression.

(*b*) This constitutes the ventricular laryngocele of Virchow. The pocket is caused by the dilatation or prolongation of the ventricle of Morgagni, and, as this dilatation occurs within the larynx, the resulting pouch may be distinguished in the laryngeal mirror. It often disappears during inspiration. A second variety of this class consists of a pocket that is continuous with the first and that may easily be distinguished from it extra-laryngeally. It is generally located in front of the thyro-hyoid membrane. Its distensibility varies with the air pressure. Its reducibility depends on the size of the channel that connects the two pockets.

II. In the cases belonging to this second main group the pocket results from a solution of continuity of the laryngeal walls. It is assumed that this begins as a hernial protrusion of the mucosa through some crack or slit in the subjacent wall, but this stage of formation has never been demonstrated. Causes leading to this initial lesion are congenital, traumatic, and post-ulcerative. In at least two cases the formation of the pocket has followed tuberculous ulceration. Trauma may occur from without or may follow such unusual increase of air pressure as results from the expulsive pains of labor, a severe cough, the carrying of heavy loads, etc. The formation of the pocket under these conditions presupposes that the aponeurosis in front of the larynx remains intact. This prevents the air from gradually diffusing itself throughout the cellular tissue of the neck.

The skin over these tumors is glossy and they may be adherent at their deeper portions. It is not always possible to reduce them, owing to the narrowness of the laryngeal fissure.

Symptoms.—These depend directly on the size of the tumor, and consist of hoarseness, aphonia, and obstruction to breathing. No case has been found in which there was any difficulty in deglutition. Externally, one may distinguish the rounded swellings which increase in size, on vocal effort, are resonant on percussion, and are generally reducible. Occasionally they are not much affected by respiration, and under these circumstances they may be mistaken for tumors of the ary-epiglottic folds. A thickening of their walls may add to their non-reducibility. The exact site at which the tumor is located varies according to the site of the solution of continuity of tissue. If this be below the glottis, a cough or a strain will cause increased subglottic tension, and this in turn will give rise to a subglottic laryngocele or tracheocele. If there is contraction of the calibre of the superior orifice of the larynx, or if the ventricular bands are the seat of an infiltration or of a new-growth, the tension is confined to the region above the glottis and the external swelling changes its position accordingly.

Prognosis.—The prognosis is good. The existence of the lesion is generally ascertained without difficulty before any dangerous stage has been reached.

Treatment.—In a case that gives little trouble, one would hesitate to undertake any formidable operation, lest the remedy should prove worse than the disease. In the internal cases, every effort should be made to remove the exciting cause. Should threatening suffocative symptoms occur, puncture of the sac relieves the emergency. Snares have been used for removing the sac. External sacs may disappear under continuous compression. If they do not, it is necessary to dissect them out after a preliminary tracheotomy has been done. Intervention is contra-indicated in cases in which an ulcerative condition (as from tuberculosis) exists. Small fistulæ may be cauterized so as to shut off the channel of communication with the larynx.*

Persistent Thyro-glossal Duct.—This appears either as an accessory thyroid gland on the tongue or as a cyst in the median line of the neck just over the thyroid cartilage. It may be somewhat unsightly, but, apart from the possibility of its becoming irritated through its exposed position, it gives no symptoms of moment. Treatment consists in the dissection of the sac from its attachments. The entrance thereto may be closed by a suture, or, if small, by cauterization.

The mode of formation can be understood only by a reference to embryological conditions. According to His, the foramen cæcum of the tongue represents the apex of a V-shaped depression which is formed by the development of the tongue from an anterior median process (tuberculum impar) and two lateral and posterior prominences which grow forward at the side of the tuberculum. It indicates the position of the epithelial outgrowth from which the median portion of the thyroid gland has been formed. As the thyroid recedes from the tongue, it becomes connected with the foramen by a long, narrow tube, the thyro-glossal duct, the upper part of which may persist as a canal leading down from the foramen to the hyoid bone. The duct represents the evagination of the hypoblast at the back of the anterior segment of the future tongue. The rudimentary portion of the thyroid gland is developed from the lower portion of the evaginated area. The upper portion of the duct proper becomes the ductus lingualis, and the lower the thyroid duct. It usually becomes obliterated as growth proceeds. Vestiges of it are the foramen cæcum, the median hyoid cornu, and various bursæ.

* Glücksberg: "Contribution à l'Etude des Laryngocèles." Thèse de Lyons, 1904; Labane: "Laryngocèle Ventriculaire," La Presse Oto-Laryngologique Belge, vol. v., 1906, p. 97.

II. SEPTIC LARYNGITIS.—FOREIGN BODIES IN THE LARYNX.—THYROTOMY.

The acute catarrhal and the acute croupous forms of laryngitis rarely, if ever, call for surgical interference, and they may therefore be disregarded in the present article.

Septic Inflammations of the Larynx.—Under this title are grouped those laryngeal inflammations which are generally designated as phlegmonous laryngitis, erysipelas, œdematous laryngitis, abscess of the larynx, etc. This topic has been clarified by Semon (*Brooklyn Med. Journal*, Jan., 1905) who observes that "as one reads accounts of various diseases of this class, he is struck with the fact that, with the exception of the commencement of the affection being located in the one case a little higher up and in the other a little lower down, or of there being in one case a serous and in another a purulent exudation, these descriptions read exactly like one another." Consequently there arises the strong probability that the same essential cause is at the bottom of them all.

When the subject of œdema of the larynx is spoken of, two sets of cases are to be distinguished, *viz.*, those of a passive and those of an active nature. In the cases of passive œdema, such as we find in the later stages of certain visceral diseases (heart, lungs, and kidneys), the affection develops without antecedent disturbance and without apparent cause. There is generally a history of depressed physique from hard work or some overstrain. In a few instances the œdema is of an angio-neurotic origin. It has been known to follow the administration of the iodides in large doses. The active variety of œdema of the larynx owes its origin to the local effects of such causes as have been referred to above, *viz.*, certain kinds of poisoning, caustic irritants, inhalations, scalding, unskilful instrumentation, septicæmia, pyæmia, etc. It is believed that some bacterial factor is at the bottom of all such cases. The organism may be a specific one, such as the diphtheria or the tubercle bacillus, or non-specific, as the Streptococcus pyogenes. Bacteria of the latter class always produce inflammation, but the exudate is not always pus. They may produce (Semon) different forms of inflammation according to their quantity, virulence, and the nature and condition of the tissues which they invade. Every one of the so-called pyogenic cocci proper is capable of producing all other forms of inflammation. Some cases are fulminating, the patient not living many hours after the initial seizure. The degree of sepsis in these cases is so extreme that, in spite of tracheotomy to relieve dyspnœa, a fatal result follows.

The initial changes may appear in the pharynx or on the tonsils, in the shape of a severe sore throat attended with considerable œdema. A peculiar bluish hue is a warning that something more than a simple inflammation is present. As the process travels downward the epiglottis becomes greatly swollen and looks like a sausage lying over the top of the larynx. The ary-epiglottic folds undergo a similar change, and there is then presented to view a large three-sac exudation. Occasionally the epiglottis may escape and the œdema may remain limited to one side only. In cases that occur in connection with acute sepsis, either of local origin or of a general nature, as in the exanthemata, the connective tissues of the neck may also become œdematous.

Symptoms —The symptoms are marked from the outset. Swallowing is painful or even impossible. Breathing is quickly embarrassed. If the cause of the obstruction is located above the level of the glottis, inspiration alone may be stridulous. If it is at the same level with the glottis, both inspiration and expiration may be affected. When it is below this level, expiration alone is affected at first. Pain is a variable factor. Cough is more or less troublesome. The laryngeal mirror at once reveals the nature of the trouble, although the exact picture will vary according to the localization of the effusion.

Prognosis.—The prognosis is always most grave in this type of case. At any time during the course of the attack the symptoms may subside and the case clear up. As soon as dyspnœa appears the surgeon must be prepared to intervene at a moment's notice.

Treatment.—Tracheotomy is the only resource in threatening cases with urgent dyspnœa. Unfortunately, this does not always afford the desired relief, for this form of inflammation shows a tendency to travel downward and involve the trachea and bronchi. Occasionally it invades the lungs and serous membranes (pericardium and peritoneum). Of course, if any threatening local focus appears incision should be promptly made. Intubation is generally unsatisfactory, if not impossible, owing to the distortion of the parts by the swelling. Heart-stimulants should be given, the kidneys and bowels acted on, and the skin kept active. Ice-coils may be used and the air kept moist by the use of a croup kettle or similar device. Any local accumulation of products should be scarified by some such instrument as the familiar laryngeal lancet. Antistreptococcus serum may be injected, but its effects are very uncertain. French has reported one case in which relief was obtained by the hourly application, to the œdematous larynx, of 1:5,000 adrenalin solution on a cotton-wrapped probe. (*Brooklyn Med. Jour.*, Feb., 1905.)

In passive œdema, such as occurs in visceral diseases, iced compresses to the throat and vigorous stimulation of all the emunctories may relieve mild cases. Scarification or puncture with the laryngeal lancet will evacuate serous accumulations, but it must be remembered that these cases frequently pass from a mild to a severe grade of dyspnœa, and that, too, with great rapidity. Cases which have developed even a mild degree of dyspnœa should be closely watched, and preparations should be made for tracheotomy if the milder measures referred to do not relieve the dyspnœa.

Foreign Bodies in the Larynx.—Foreign bodies, such as pins, needles, coins, buttons, tooth-plates, bits of bone, and other hard substances may be drawn into the larynx during inspiratory efforts, mastication, swallowing, laughing, etc. Vomited material may be similarly aspirated. Rarely, sharp bodies may enter by penetration of the cervical tissues or through fistulæ. In children who have the habit of holding things in their mouths such accidents frequently happen during sleep. Natural sensitiveness is somewhat in abeyance at this time, and the usual reflex efforts at expulsion may not take place. Smooth and rounded bodies are naturally more apt to slip down than others.

Symptoms.—Fluids, unless of a caustic nature, do not usually cause any trouble beyond the momentary choking followed by spasmodic coughing. In the case of solid objects the symptoms vary according to the size, shape, motility, and position of the body inhaled. They consist of vocal impairment, irritation, pain, cough, and varying degrees of dyspnœa. Occasionally the onset of such symptoms is the first intimation the patient has that anything has been drawn into the larynx, he not being aware that any such accident has occurred. As a rule, however, the entrance of the body immediately sets up glottic spasm. Unless relief is at hand, a fatal result may follow from asphyxia. The acute symptoms may subside, to be renewed with lessened severity. The subsequent appearance of cough, with blood-streaked or purulent expectoration and possibly with septic manifestations, indicates that suppuration has occurred. This process may set free impacted bodies, which are then expelled, all symptoms ceasing with their expulsion. The foreign object may often remain *in situ* for months, causing surprisingly little disturbance. Flat bodies, such as coins and buttons, are often found in the laryngeal ventricles, while pins, needles, and other sharp bodies are more apt to lodge in the epiglottis, the ary-epiglottic folds, or the ventricular bands. Pins may lie head downward or may be so embedded as not to reveal the relative positions of head and point. This arises perhaps from the fact that they are generally held in the mouth, point out, or that, in their descent, their position becomes reversed by adaptation of their centre of gravity. The movements of swallowing may fix a body which previously was only partially attached.

Reference should be made also to a class of obtuse patients in whom this accident may easily happen—*viz.*, those whose nerve centres are affected and in whom the naturally sensitive larynx has become blunted. A common accident in such cases is the development of a foreign-body pneumonia, and all such patients take solid food only with more or less risk of this complication. The possibility of the presence of a foreign body should always be thought of in a case of persistent laryngeal irritation without apparent cause. (See also the section on Spasm of the Larynx, on page 896.)

Inspection with the mirror or with the Kirstein spatula generally makes it possible to locate a foreign body. The utility of the x-ray in such cases is convincing. Palpation is at times serviceable. Temporary lodgment in the pharynx, with subsequent swallowing of the body, may leave behind symptoms of irritation that are referred to the larynx.

In all such accidents Nature endeavors to afford relief through the act of coughing and the subsequent expulsion of the foreign body through the channel of entrance. If the body can be located efforts at removal should be made through the mouth. Threatened asphyxia may demand immediate tracheotomy. If the initial symptoms subside there is time to select a proper instrument wherewith to remove the offending substance. If the impacted object is heavy and loose, inversion of the patient's body may dislodge it. The old practice of slapping children vigorously on the back or holding them upside down is rational, though not always efficacious. If the foreign object is sharp and impacted, emetics must be carefully avoided, though they may relax glottic spasm in the case of smooth and rounded bodies. The mere act of coughing will rarely dislodge the foreign body if it has gone down as far as the larynx. Sometimes the treatment of resulting inflammatory swelling, if conditions permit, enables us to grasp a body not at first accessible. Local anæsthesia, in the case of an adult, and general anæsthesia in children, are

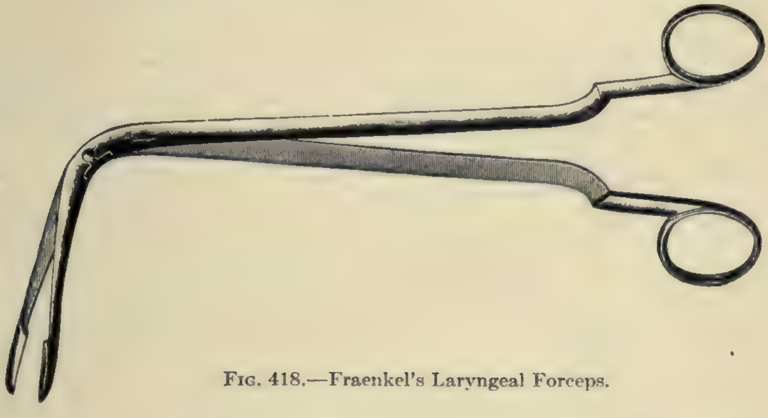

Fig. 418.—Fraenkel's Laryngeal Forceps.

important preliminary measures. In the employment of a general anæsthetic it is wise to begin with nitrous oxide gas. It lessens struggling with its attendant danger of further intra-laryngeal damage.

As to the choice of means for removing the foreign body through natural channels, we find in Fraenkel's or Mathieu's forceps (Fig. 418), or some modification thereof, an instrument which will meet every indication. After removal has been effected it is well to allay irritation by the use of sedative inhalations, such as eucalyptol, the familiar compound tincture of benzoin, etc. Patients who wear tooth-plates, particularly small ones, should always remove them on retiring.

In certain cases it will be deemed necessary or advisable to remove the foreign body through an artifically made channel; and here the following general rules may prove helpful. In the case of a large angular body in the larynx, where any attempt to remove it *per vias naturales* would surely cause laceration of the tissues, thyrotomy is clearly indicated, the only possible danger of the operation being an impairment of the vocal powers. In the case of a small smooth body, which is impacted above the true cords and which can be passed through the artificial opening or pushed up through the mouth, it will be best to make an incision through the crico-thyroid membrane. In the case of a large foreign body, impacted in the lower larynx, laryngo-tracheotomy is indicated. Finally, if the foreign body is impacted in the upper larynx in such a manner that direct access is required, pharyngotomy (subhyoid or lateral) will be the preferable operative procedure. These operations call for a preliminary tracheotomy.

III. SYPHILIS.—TUBERCULOSIS.—LUPUS.

Syphilis of the Larynx.—The most natural division of this subject is into hereditary and acquired varieties of the disease. As regards the hereditary, and especially the congenital, manifestations of syphilis in the larynx it may be said that they are more common than is generally believed. They are often undiscovered simply because they are not looked for. Some of the sudden œdemas and suffocative attacks of early life are referable to this cause. Syphilis should always be suspected in the case of an emaciated and cachectic child whose voice is husky and who has difficulty in swallowing, a short cough, and frequent attacks of laryngismus stridulus. Generally there are, in addition, suspicious symptoms referable to the eyes and teeth.

As soon as a diagnosis is reached the child should at once be put on a course of hydrarg. cum creta. In cases requiring rapid medication we may use the bichloride (one-sixtieth grain four times daily) or calomel (one-tenth grain). For inunction we may employ the officinal Ung. Hydrarg. (ten grains to the ounce of white vaseline) under the general precautions governing this method of medication.

Some cases of laryngeal stenosis of syphilitic origin require prompt surgical intervention. Tracheotomy may be required as an emergency measure or as a preliminary to the attempted dilatation of the stenosed area with bougies, etc. Intubation with rather larger (metal) tubes than those generally used has yielded good results. Gradual dilatation with the Schroetter tubes has also proven satisfactory. In addition, there are various cutting instruments which may be employed in overcoming the stenosis, but systematic dilatation is still necessary after the use of these instruments. It is surprising how well all this instrumental interference is borne by the patient. Unfortunately, the removal of these dilators is often followed by re-contraction of parts which seemed to have undergone permanent dilatation.

In the acquired form of the disease the lesions belong to the secondary and tertiary periods. One case of epiglottic chancre has been reported. (Moure.) The earliest secondary manifestation is the erythema, which may appear about six weeks after inoculation, though generally it manifests itself much later. In the absence of a definite history the appearance of the larynx may not excite suspicion. The mucous patch may be found on the vocal cords. Erosions of various depths, due to the breaking down of either a mucous patch or a superficial gumma, are not uncommon lesions. Condylomata of the larynx have been noted.

The most important specific lesion of the larynx, in the sense of frequency and potentiality for harm, is the gumma, which may not appear for six or eight years after inoculation, the patient in the mean time having been free from laryngeal symptoms. The gummatous process may be diffused or circumscribed. When a case comes under observation, it is generally found that ulceration has already begun—a circumstance which may be explained by the facts that the larynx is never at rest, and that consequently gummata here break down early from unceasing irritation.

Symptoms and Diagnosis.—The accompanying symptoms depend on the size and location of the gumma. They consist of discomfort, not much actual pain, some dysphagia when the lesion is situated on the posterior wall and affects the œsophagus, and possibly dyspnœa. The sudden appearance of the gummatous mass, and its stationary character—except when reduced in size by ulceration—are points of value in diagnosis. The immediate danger is the formation of a deep tertiary ulcer, excavated, covered with yellowish secretion, and surrounded by a reddish, angry-looking zone the borders of which are sharply defined. This condition is followed by the formation of cicatricial bands of various kinds and by contraction of these tissues.

Treatment.—Treatment depends on the degree to which the process has advanced. As soon as the nature of the disease is recognized, the patient should be placed on the iodides in increasing doses, and in addition mercurial inunctions or injections should be employed. In case dyspnœa is threatening tracheotomy is called for. It cannot be too strongly urged that, notwithstanding the fact that some of these patients seem to breathe comfortably through very much narrowed larynges, there is always the danger that a spasm or an œdematous condition of the larynx may completely close the narrowed breath-way. The onset of dyspnœa, therefore, is a sign that the patient should be placed under surveillance, as immediate tracheotomy may be called for at any time. Ulcerated areas should be kept clean with the alkaline sprays and antiseptic dusting powders such as iodol, nosophen, etc. For the relief of cicatricial stenosis we may employ the large intubation tube, Schroetter dilators, etc.

Tuberculosis of the Larynx.—Tuberculosis of the larynx is rarely primary in character, the laryngeal lesion being, in the vast majority of cases, consecutive to pulmonary disease. Probably one-third of all cases of pulmonary tuberculosis present tuberculous lesions in the larynx, although in only from one-eighth to one-seventh are destructive changes developed. Primary laryngeal tuberculosis arises either from direct lodgment of the infection on the mucosa or from a transference of the same to the mucosa by way of the lymphatics. Most of the secondary cases are the result of invasion through the lymphatics.

The tuberculous process in this locality follows the usual course of tuberculosis elsewhere in the body. There is first a deposit of tuberculous material beneath the mucosa, and from this centre the disease extends to the surface, a typical tuberculous ulcer being thus formed. The sites most frequently involved are the posterior commissure, the arytenoid region, the ary-epiglottic folds, the true cords, and the epiglottis. The infiltration may at times take on enormous proportions before an actual breaking-down of the tissues occurs. In a typical case there will be seen pear-shaped swellings of the arytenoids, with perhaps a turban-shaped infiltration of the epiglottis. Ulcers, which at first are minute and scattered, may finally coalesce into a single lesion. In other cases the effects of the tuberculous process are seen in the form of large areas of rather dense infiltration or even sometimes in that of distinct tumors; in other words, there is hypertrophy rather than destruction of the infected tissues. The tumors observed are regarded by some authorities as anatomically allied to granulation tissue and as a natural step toward cicatrization.

Symptoms.—The initial symptom is an impairment of the voice, which for a while may come and go. Cough soon appears. At first it is dry and comes on in a jerky manner whenever the patient attempts to speak. Later, it becomes more pronounced and is accompanied by expectoration of thick tenacious mucus. Finally, there is the typical muco-purulent or purulent sputum. Hemoptysis, as a symptom of laryngeal disease, is not common. Local pain is present if the cartilages have been invaded. Later comes the painful swallowing which is so distressing and so quickly wears down the patient, both from his inability to take the proper amount of nourishment and from his unwillingness to make the attempt on account of the agonizing dysphagia.

The general symptoms are the same as those of active tuberculosis in any part of the body.

Prognosis.—The prognosis is of course unfavorable, but some cases seem to recover so far as concerns the activity of the local process, and that too with all forms of treatment as well as with no treatment at all.

Treatment.—Treatment consists of the usual hygienic, dietetic, climatic, and internal measures. We concern ourselves here particularly with topical applications and surgical intervention.

Concerning the former we may state that one most important indication is to enable the patient to swallow comfortably. The local use of morphine for this purpose has been superseded by that of cocaine, eucaine, and their congeners. The danger of acquiring the drug habit must be estimated, but it is often overruled by the appeals of humanity. A remedy which has found much acceptance is orthoform, to be insufflated or to be applied in emulsion. A good formula is that of Freudenthal who prescribes the following:—menthol, 10; oil of almonds, 30; yolks of two eggs; orthoform, 12; distilled water, 100. Wolfenden advises that the patient should lie flat on his stomach, with his head over the edge of the bed, and that he should draw up through a tube fluid from a vessel at a lower level; *i.e.*, he should drink as an animal drinks. A soft rubber catheter may be passed into the œsophagus, and through this instrument fluids may be forced into the stomach from a rubber bottle. The patient should not use his voice.

Topical treatment commences with local cleanliness. All remedies should be soothing, and the utmost gentleness should be employed in applying them. The aim of such treatment is to reduce the hyperæmia and to remove the tenacious secretion. Sometimes the usual alkaline solutions of the Seiler-tablet order are sufficient. Hydrogen dioxide diluted with lime water is of service in case of adherent secretion. Enzymol, a proteolytic ferment, may be diluted with an equal quantity of warm water and used in a similar manner. It attacks only dead tissue and is of service in clearing off ulcers. It should be followed by the use of the warm alkaline solution. Various powders, such as iodol, aristol, etc., are used with the idea of securing local antisepsis. Menthol (twenty per cent in olive oil) is a favorite remedy with many. Its curative power is a matter of dispute, but it undoubtedly relieves local discomfort. With a view to bringing about the absorption of infiltrated material the employment of weak sprays of formalin has been suggested. The use of these sprays is somewhat painful unless previous local anæsthesia has been practised. A favorite formula for ulcerated surfaces is the following: morphine and cocaine (one-quarter grain of each), and boric acid and iodoform (one grain of each), the whole to be utilized in the course of the day, in two or three separate insufflations. These may be given before meals to relieve dysphagia, and again at bed-time to induce sleep. The longer the use of morphine can be postponed, the better for the patient's general well-being.

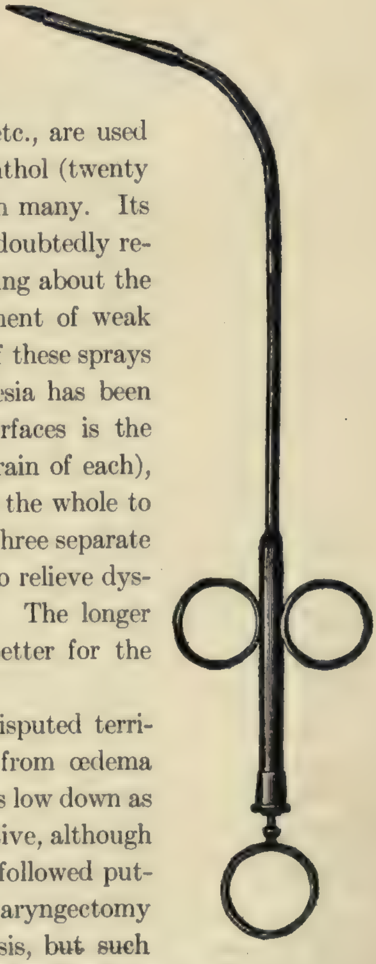

Fig. 419. — Tobold's Laryngeal Lancet.

In discussing surgical measures we are on disputed territory. Tracheotomy for the relief of dyspnœa from œdema may be necessary. If it is, it should be done as low down as possible. It is to be regarded merely as a palliative, although in some instances remarkable improvement has followed putting the larynx at rest. Both thyrotomy and laryngectomy have been done in cases of laryngeal tuberculosis, but such radical procedures do not commend themselves as justifiable under the conditions usually present. Œdematous tissues may be incised by curved knives or scissors. The familiar laryngeal lancet (Fig. 419) may be used for making scarifications. These procedures are followed by the escape of blood and serum, and give considerable local relief. Submucous injections of creosote and its allies, as performed by Chappell, Watson Williams, and others, have afforded benefit. The galvano-cautery has been suggested for the destruction of fungoid masses and flat infiltrations not easily grasped by a cutting instrument. In the hands of a few, cupric interstitial cataphoresis has been attended with good results.

The surgical procedure most commonly followed is that of scarification or excision, followed by the *rubbing in* (not mere mopping) of lactic acid. This plan of treatment has been popularized by the work of Heryng and Krause. The curettes

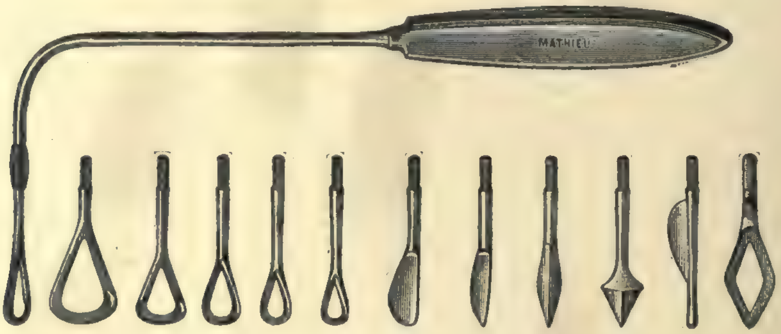

Fig. 420.—Heryng's Laryngeal Knives and Curettes.

of the former are here figured. (Fig. 420.) It may be necessary to subject the patient to a course of training before one can safely intervene. Thorough local anæsthesia is required. The obscuration of the operative field by the escaping blood can be lessened by the application of adrenalin. Under the guidance of the mirror the parts are attacked according to our judgment of the location of the disease, and the acid (strength twenty per cent) is then rubbed in. Subsequently the strength of the acid may be gradually increased. Pain is usually severe for a short time, but, in order eventually to secure cicatrization, it may be found necessary to continue the use of the acid for two or three months. Applications should not be made, under any circumstances, oftener than once a week. If the epiglottis is much infiltrated it may be removed wholly or in part by means of curved scissors. All of these measures are justified by the fact that they afford the patient much relief, as regards the dysphagia, while at the same time the advance of the disease steadily continues. The general condition of the patient must be taken into the account before anything is attempted. Cases with much pulmonary involvement, and those in which the disease is specially active, are manifestly unsuitable for this plan. Recent observations on the effects of sunlight and the electric light seem to promise much in the way of affording some degree of relief for the local disease. These agents are applied by means of an apparatus which focuses the rays directly upon the external laryngeal tissues. The fact seems to be established beyond a doubt that many cases of laryngeal tuberculosis have been benefited by the employment of one or the other of the three leading methods—electric light, sunlight, and Roentgen rays. The Roentgen rays find here the same limitation as in other fields; that is, it is difficult to apply them directly to the lesions. The effect of these rays on deep-seated lesions, when they are simply focused upon the corresponding cutaneous areas, must be regarded as problematical. Freudenthal has devised a modified Voltolini lamp by means of which the electric light can be applied externally to either side of the larynx or upon the pomum Adami. The apparatus contains an Edison lamp, and in front of the latter is a water-filled ball which acts as a biconvex lens and also protects the skin from the effects of too intense heat. The front part of the apparatus is covered with India rubber so that it adapts itself to the cervical contour. Freudenthal has reported marked amelioration in several cases. He finds that the duration of an application should not exceed five minutes. Similarly, the rays of the sun may be concentrated upon the laryngeal area. Reports from sanatoria in which this plan has been tried are very encouraging.

Lupus of the Larynx.—Lupus is now regarded by many as an attenuated form of tuberculosis. Primary disease of the larynx is rare, most cases occurring in connection with lupus of the skin or of the air passages higher up. It is estimated that from eight to ten per cent of all cases of cutaneous lupus show evidences, sooner or later, of laryngeal invasion, and this may occur without the involvement of the intervening faucial regions.

The epiglottis is the portion of the larynx most frequently invaded. Favorite sites of the process in the soft parts are the ventricular bands and the ary-epiglottic folds. The disease begins here as elsewhere by infiltration and the formation of nodules which later ulcerate and contract. Fresh lesions make their appearance while the areas first involved heal. The most bizarre appearances of the larynx may result from the cicatricial bands which form.

One of the earliest symptoms is a husky voice. If the lupoid deposits encroach on the lumen of the passage dyspnœa will result. Pain in swallowing is but slight, at the most. Rarely is there any inflammation or œdema.

The course of the disease is typically chronic. It may last for years with surprisingly little disturbance.

Treatment.—Constitutional treatment follows the same lines as for tuberculosis. Local measures may be required on account of the dyspnœa. It seems to be a fortunate characteristic of the local lesion that, if stenosis occurs, it develops at a comparatively early stage. The affected areas may be scarified, curetted, and rubbed with lactic acid. The galvano-cautery should be applied with great caution. Many measures that are adapted to the disease as it occurs on the skin are obviously inapplicable in the larynx. If the stenosis becomes severe, intubation or tracheotomy must be considered. The x-ray has been applied from without, but thus far without much benefit, so far as laryngeal lesions are concerned. A similar observation may be made with reference to the Finsen light treatment.

Fortunately, the progress of a given case is so slow that ample time is at hand for selection of the plan that is most likely to prove beneficial.

IV. BENIGN GROWTHS.—MALIGNANT DISEASE.

Nothing more is known about the causes of tumors in the larynx than about their occurrence elsewhere. A few of them are congenital. In some cases there is a history of vocal overstrain. Doubtless any cause leading to laryngeal catarrh is a predisposing factor. Laryngeal tumors are far more common in the male sex and, with the exception of papilloma, they are generally limited to adult life.

Benign Growths.—According to the size and the location of the growth in the larynx, the alterations in the voice are more or less pronounced. They are very noticeable, for example, when the tumor involves the true vocal cords. Then, again, a small sessile mass is more apt to give trouble than a larger one which is pedunculated. The latter causes disturbances which vary in degree according to the locality where the tumor may happen to be. If it is attached to the epiglottis, the ventricular bands, or the ary-epiglottic folds, so that approximation of the true cords is not hindered, it may attain a surprisingly large size before attention is drawn to the actual condition. Local irritation may be present, and it is sometimes sufficient to cause actual pain. If the growth is seated above the glottis cough is generally absent. In children laryngeal spasm is frequent under these conditions. If the growth, however, is situated below the glottis dyspnœa of varying intensity is more common than it is in growths that are seated higher up. Spontaneous bleeding is rare. Blood may escape as the result of attrition, but free bleeding at once arouses a suspicion of malignancy. The development of a tumor of this character often takes place so slowly, and the interference with the breathing increases so gradually, that a considerable size may be attained before much attention is paid to the state of affairs in the larynx. Then a severe cold, by inducing an additional swelling of the laryngeal mucosa, causes the patient considerable discomfort and thus leads to the discovery of the tumor. Lewin has stated that if inspiration is more impeded than expiration it indicates that the growth is above the true cords.

VARIETIES.—The varieties of benign growths are here stated in the order of their relative frequency:—

(1) Papilloma, a wart-like growth that often takes on a cauliflower-like appearance. It is usually confined to the anterior portions of the true cords, and is generally pedunculated. At times the mass may overtop the site of attachment and appear sessile.

(2) Fibroma. This belongs to a later period of life and varies in size from a minute mass to one quite filling the laryngeal cavity. It is generally attached to the true cords and is sessile, consisting of interlacing connective-tissue fibres

containing branching cells. It has a scanty blood supply and the overlying mucosa is hyperæmic. It is often simulated by the so-called prolapse of the laryngeal ventricle. This condition, which was formerly regarded as a true prolapse of the ventricular lining, is now regarded as the result of rapid swelling of, or the entanglement of foreign material in, the ventricle itself. (Shurly.) In some cases the condition seems to result from injury. Careful use of the probe will distinguish it from true fibroma.

(3) Cystoma. This condition originates from occlusion of a gland duct or from cystic degeneration of a gland lobule. It occurs on the true cords, in the laryngeal ventricle, and especially on the epiglottis. When the tumor is seated on one of the vocal cords, it presents either a transparent or a milky appearance, but when it is seated higher up it is opaque. Cystoma belongs to the middle period of life, and when once removed it rarely returns. The contents are generally mucoid in character, but at times they present a colloid and occasionally a bloody appearance. Tervaert collected records of ten cases in which the sacs seemed to contain only air. Such cases are looked upon as congenital enlargements of the sacculus laryngis.

(4) Myxoma. This variety of growth may be pedunculated or it may appear as a diffuse sessile infiltration.

(5) Lipoma. A few cases of laryngeal lipoma are on record, some of them being congenital.

(6) Angioma. This form of growth, which is rarely observed in the larynx, presents no peculiar features.

(7) Adenoma. The existence of true adenoma in the larynx has been denied; certainly very few alleged cases have been recorded.

(8) Ecchondroma. An ecchondroma may grow from any of the laryngeal cartilages. Growths of this nature are confined to adult life and are generally composed of pure hyaline cartilage. Later, this hyaline cartilage may become fibrous and infiltrated with bone salts.

Among the other growths which have been found may be mentioned lymphoma, accessory thyroids, and amyloid masses.

Course and Prognosis.—The natural course of all benign growths is to increase in size. The prognosis is good as to non-recurrence after removal except in the case of papilloma, which often returns with exasperating frequency. In one instance a papilloma was expelled during a paroxysm of coughing in pertussis.

Treatment.—Treatment of most of these benign tumors is generally very satisfactory. If they are thoroughly removed they do not recur. As stated above, papilloma forms an exception to this latter statement. In commencing the treatment of a given case the surgeon should train the patient to relax his throat and to overcome the natural dread of intralaryngeal manipulation. Cocain is of great service in effecting this result. A five-per-cent solution may be applied to the upper throat to lessen reflex irritability; a ten-per-cent solution may be sprayed into the larynx; and, at the time of the operation, a few drops of a twenty-per-cent solution may, under the guidance of the mirror, be dropped directly on the growth by means of a laryngeal syringe with a long, curved cannula. All instruments should be warmed and may be smeared with some bland oil. It is advised to introduce them closed a few times so as to accustom the tissues to their presence before any attempt is made at removing the tumor. It is not wise to introduce instruments too many times at one sitting, and the sittings should not follow each other too frequently. The effects of instrumentation upon the respiration will be a good guide of action in such measures. The end aimed at is to close the blades of the instrument employed directly

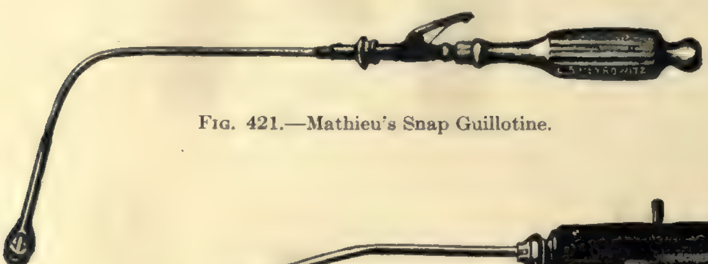

Fig. 421.—Mathieu's Snap Guillotine.

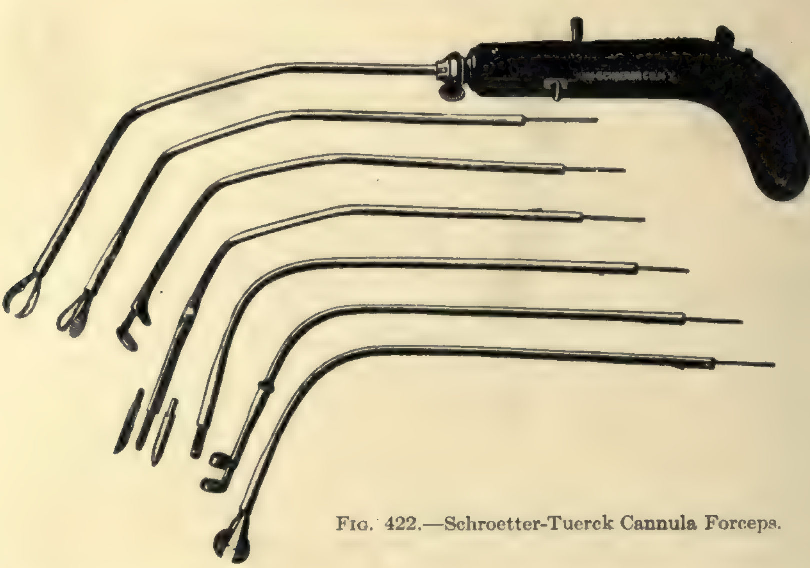

Fig. 422.—Schroetter-Tuerck Cannula Forceps.

upon the mass, any blind application, especially of the cutting edge, being carefully avoided. Growths that appear to be soft may prove quite hard. After the removal of the tumor the patient should keep quiet for a day or two, should not use his voice, and should suck ice pellets from time to time. Sedative inhalations and alumnol sprays may be used to advantage. It goes without saying that no case should be dismissed before the passages above (nose, pharynx, etc.) have been placed in proper physiological condition.

Some papillomata have disappeared under the application of absolute alcohol dropped on them by means of a syringe. This remedy, so far as the removal of the papilloma is concerned, is very uncertain in its action, and at times is dangerous. For the removal of growths on the edges of the cords, some surgeons prefer the snap-guillotine of Mathieu (Fig. 421) or one of the various forceps often used for such purposes. (Figs. 422 and 423.)

Frequently, in cases of papilloma, the removal of the growth, though done in a seemingly thorough manner, is followed by recurrence. Under these circumstances it has been proposed to insert a tracheotomy tube, in the usual manner, so as to place the larynx completely at rest. This procedure has been carried out successfully, and the result has been a gradual disappearance of the growth. In most instances the tumor has not returned after the tracheotomy tube has been removed. Unfortunately, in a certain number of cases the restoration of laryngeal function has been followed by the recurrence of the papilloma. The tracheotomy tube should at first be of small size, as Lennox Browne has called attention to the danger of pulmonary damage from allowing the sudden inrush of a large amount of air through the tracheal opening as compared with the much smaller amount to which the patient has become accustomed from the presence of the laryngeal obstruction. It has been proposed to insert a fenestrated intubation tube so as to allow the growth to protrude through the fenestra, and then to follow this procedure by the removal of the tumor with the usual instruments. All of these manipulations for removal are of course done under the guidance of the mirror, the patient holding the protruded tongue.

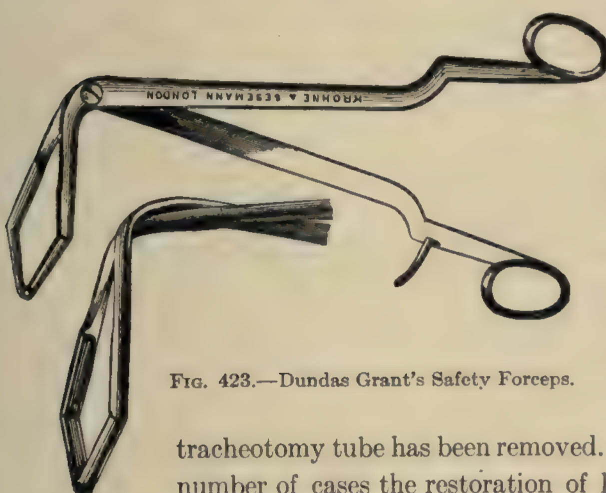

Fig. 423.—Dundas Grant's Safety Forceps.

Other devices for removing intralaryngeal growths include the familiar cold-wire snare. The adjustment of this mechanism to growths which are situated low down in the larynx is difficult. The stump that remains after the removal of one of these growths in either of the ways described, should be cauterized. Chemical caustics in this field have been largely abandoned owing to the difficulty of limiting their action in a vital area. This difficulty of strictly limiting the action of the caustic has been overcome in some degree by the employment of a bead of chromic acid fused on the end of a probe. The use, however, of the galvano-cautery at a dull-red heat is the plan now commonly adopted.

If the patient is an adult, local anæsthesia will suffice for all these manipulations. The Kirstein spatula may be used in intractable cases, but instruments suitable for removing the growth must then be of a special shape. In children it is usually necessary to resort to the employment of a general anæsthetic. This should be carefully administered, and the child slowly brought to an upright position, so that the practitioner may be able to operate in the usual way. For this purpose chloroform is preferred, in combination with local applications of cocaine to lessen reflex irritability. In recent years the use of straight tubes passed down to the larynx and the removal of the growth under direct inspection has become more common.

If none of the foregoing methods is applicable to a given case, the question arises whether a tracheotomy tube should not be introduced and an opening made in the larynx, so that the growth may be reached directly and radically extirpated. Surgically, this is a simple method to follow, but it has certain disadvantages. Experience seems to show that recurrence is more common after thyrotomy than after endo-laryngeal methods. Moreover, in certain cases, in which the operation seemed at the time and for some months afterward to have been successful, stenosis eventually developed and necessitated the permanent retention of the tracheotomy tube. Finally, while a thorough removal may certainly be effected by this method, there is danger of permanent vocal impairment. This danger is lessened by avoiding the complete section of the thyroid cartilage. If a small bridge be left at the top adjoining the notch, subsequent coaptation can be accurately made. With the progress made in recent years in perfecting endo-laryngeal technique the need of thyrotomy for the removal of benign growths is becoming less apparent.

Malignant Growths.—Practically, there are only two kinds of laryngeal malignant growths—sarcoma and carcinoma.

Statistics show that sarcoma is relatively uncommon. Gurlt notes that, out of eight hundred and forty-eight cases of sarcoma seen in two of the Vienna hospitals, there was but one case in which the larynx was involved. During the same period sixty-two cases of carcinoma of the larynx were found out of a total of nine thousand five hundred and fifty-four cases of cancerous disease in general.

Sarcoma.

Laryngeal sarcoma occurs three times as often in men as in women and is generally confined to the middle and later periods of life. It may occur at any age after puberty. It develops at an earlier age in the female sex than in the male. As to its special cause, nothing is known. All the usual varieties are found in the larynx, the relative order of frequency being spindle- and round-celled, alveolar, and giant-celled. Most of the recorded cases have been located on the true cords. If the larynx is primarily attacked, the tumor seems to confine itself thereto, not extending to the pharynx; but if the latter is primarily affected, the larynx generally becomes involved. Ulceration is a late feature, while erosion of the cartilages occurs only rarely.

Symptoms.—The symptoms comprise vocal impairment, gradual interference with respiration, and more or less cough. Pain is not a prominent feature, but if the epiglottis becomes involved there is more or less dysphagia. In about one-seventh of the recorded cases the cervical lymph nodes were involved, and this happened more commonly when the primary tumor was of the round-celled or the alveolar variety.

Course of the Disease.—The duration is indefinite. Some patients come under observation after complaining for only a few weeks, while others state that they have suffered for many years. The round-celled and alveolar forms grow the most rapidly.

Diagnosis.—The diagnosis is a matter of conjecture, unless we obtain the results of a microscopical examination of a portion of the growth. There are certain facts, however, which are not without diagnostic value. Thus, for example, ulceration comes on later in sarcoma than in carcinoma; pain is less in the former than in the latter, and yet the rapidity of growth is, as a rule, greater in sarcoma; and, finally, projections from the central mass of a sarcoma are more apt to be broad and rounded as compared with the irregular infiltration of a carcinoma.

Prognosis.—The prognosis is the same as for malignant growths in general. The outlook for the prolongation of life is more favorable for sarcoma than for carcinoma.

Treatment.—The treatment is purely surgical and will be considered under the heading of Carcinoma. The use of the erysipelas toxins for laryngeal sarcoma has thus far been without any definite results.

Carcinoma.

Under this heading reference is made to those growths which invade the larynx primarily, and not to those which encroach on it from surrounding tissues. The relative frequency of carcinoma is shown by the well-known statistics collected by Semon at the time of the illness of the German Emperor Frederick. Ten thousand seven hundred and forty-seven cases of benign, and fifteen hundred cases of malignant growths of the larynx were collated from statistics of one hundred and forty-seven reporters. The same figures also show that benign growths rarely, if ever, become malignant, even under the irritation of operative intervention. Tumors may change their type. The limited value of the findings of the microscope arises from the fact that the fragment examined does not always include all the tissue elements of a given tumor. Carcinoma is three or four times as common in men as in women. The general principle of heredity as applied to cancer is pertinent here also. A few cases have been reported in young children, but most of them occur between the fortieth and the seventieth year of life. The disease seems more common in the higher walks of life.

Many of the patients have been persons who are obliged to use the voice a great deal, and many have been excessive smokers, but nothing definite as to the cause of this special localization can be stated.

The most common variety is epithelioma. Other varieties reported from time to time have been combinations with adenoma, schirrhus (rare), and encephaloid. Adeno-carcinoma appears to grow more slowly than do the other forms and, in so far, is more favorable for operation. Different parts of the larynx may be affected, the left side by preference. The ventricular bands form the most frequent site of origin. Other starting-points are the true cords, the epiglottis, the commissures, and the ary-epiglottic folds. Two main classes of growths are recognized as to location, *viz.*, intrinsic and extrinsic. In the former the cervical lymph nodes are not involved until a very late stage of the disease, if at all. This relative immunity is referable to the peculiar arrangement of the lymphatics, not to their scarcity in the laryngeal box. Even in intrinsic cases the lymph nodes at the sides of the trachea and bronchi are often invaded. In extrinsic cases the node most often involved is one that lies at the level of the anterior border of the sterno-mastoid muscle, at the height of the space separating the hyoid bone from the thyroid cartilage.

Symptoms.—The initial symptom is huskiness of the voice, sometimes amounting to actual hoarseness. Later, there are weakness and perhaps even loss of the voice. Cough and dyspnœa may be added. The movements of the larynx become sluggish on the affected side. Pain is at first felt only on swallowing; later, it is felt intermittently and without any relation to this act; and finally it is constant. It is generally worse at night. Appetite fails, emaciation appears, and finally there is the usual cachectic condition. The site of the growth determines the relative order of appearance of the symptoms. Salivation is common, and the later stages of the disease are characterized by ulceration, foul discharge, and possibly hemorrhage. In the latest stages the intrinsic growth may penetrate the cartilages and appear in the neck as a fungous mass. Cartilaginous sequestra, as well as pieces of the growth, may be coughed up by the patient. Tracheotomy may become necessary to prevent suffocation due to direct encroachment of the growth on the lumen of the larynx. Death results from exhaustion, from inspiration pneumonia, from suffocation, or, in rare instances, from hemorrhage dependent upon the erosion of a large blood-vessel.

Diagnosis.—The question of differential diagnosis brings the surgeon face to face with one of the gravest problems in the entire field of laryngeal practice. In view of the terrible nature of the disease and the necessity for early intervention, recognition of the exact nature of a laryngeal tumor becomes a matter of the greatest importance. In its initial stage there is no absolute sign or symptom indicative of the disease. Three methods of examination are at our disposal. J. N. Mackenzie enumerates them in the following order of relative importance: 1st, the naked-eye method, or diagnosis by direct inspection, supplemented by clinical phenomena; 2d, a resort to thyrotomy, which enables us to determine the amount of tissue involved (even this method is not always accurate, for tissues apparently normal may contain the advance cells of cancerous infiltration); and 3d, the use of the microscope.

At first thought nothing would appear more rational than to remove a portion of the growth, subject it to the microscope, and, on the findings thus determined, base the subsequent course. It is probably the plan most often followed. But practical objections thereto exist. Such a course subjects the patient to danger of auto-infection at the point of incision and to metastasis to other sites. Furthermore, it may stimulate the growth of the tumor, and is often inconclusive, misleading, and at times impossible. (Mackenzie.) Some surgeons are unwilling to remove a fragment for examination unless the patient consent immediately to submit to radical treatment if the findings should demonstrate malignancy. It should be observed, however, that malignant tumors here, as elsewhere, do not grow with a regular rate of increase. After a period of quiescence they may suddenly start up in renewed activity without apparent cause and grow at a much more rapid rate. Hence, if the removal of tissue for diagnostic purposes should happen to coincide in time with one of these periods of recrudescence, the removal of the small piece of tissue would be credited with having caused the latter. This is one of the arguments used to justify the position of those who counsel against the removal of tissue for examination. The facts, however, do not justify the position which these men assume. Thus, for example, Chiari * noted rapid increase in only one instance out of twenty-eight such exploratory incisions.

Some epitheliomata resemble papillomata in their gross appearance. Jurasz calls attention to the fact that malignant tumors seem to grow into, rather than out of, the underlying tissue. A snow-white color has been regarded as evidence of malignancy. Semon states that if we "find a growth of this color, which at first suggests papilloma, but the eminences of which are not so bulbous and rounded as in the latter, being rather sharp-pointed like grasses, we have strong reason to believe in its malignancy."

As to the value of age in differential diagnosis, it may be said that in patients under thirty the growth is probably not malignant, whereas after fifty it probably is malignant if occurring in a larynx that was previously free from disease. Pedunculated growths are probably benign if, after a lapse of several months, there be no evidence of surrounding inflammation or infiltration. Sluggish movements of the cords, especially if associated with a husky voice, are very suspicious.

The average patient is apt to present an area of infiltration surrounding a central focus. In the great majority of cases the question at once narrows itself down to a decision between tuberculosis, syphilis, and cancer. As to tuber-

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culosis we should bear in mind that there are certain cases in which the hyperplasia manifests itself in quite a different form from that presented in the familiar pear-shaped arytenoids. In order to get at the truth we should carefully examine the sputum, take the body-temperature, and ascertain the condition of the lungs and other organs predisposed to an invasion of tubercle bacilli. Evidence should be taken from a wide field, and considerable time will have to elapse before we can render a positive judgment. In syphilis, the body should be carefully examined for stigmata of the disease, due attention being given to the previous history and the patient being given the benefit of the therapeutic test. The iodides often reduce the size of the inflammatory zone surrounding a malignant deposit without at all affecting the tumor proper. Hence, under the use of this drug, there is an illusive temporary benefit which is not borne out by subsequent progress. Finally, we should remember the possible combination of malignancy with either tuberculosis or syphilis. This caution applies especially to those growths which start inside the larynx as rounded swellings or infiltrations, and from which it is extremely difficult, if not impossible, to remove a fragment for examination.

Prognosis.—If surgical intervention is not resorted to life is rarely prolonged, except in case of adeno-carcinoma, more than three years from the first appearance of the disease. Adeno-carcinomata pursue a somewhat slower course.

Treatment.—Palliative measures for the relief of symptoms are demanded on simple humanitarian grounds. Pain is the feature most distressing to the patient. Local measures should be tried before we resort to the internal use of anodynes. Among the applications which have proven of service the following may be mentioned:—

℞ (Ingals' Mixture.)

Morphine	gr. iv.
Tannic acid,	
Carbolic acid	of each gr. xxx.
Glycerin,	
Distilled water	of each ℥ ss.

℞ (Mixture of C. H. Knight.)

Carbolic acid	ʒ iss.
Tincture of iodine	ʒ iv.
Glycerin	ʒ ij.

Solutions of cocaine and nirvanin act promptly, but their effect is of brief duration; and when one has once begun to use them it will be found extremely difficult to abandon them. Orthoform, a yellow powder, may be insufflated on ulcerated surfaces and will often afford relief for several hours, during which interval nourishment may be taken. Alkaline washes clear away the débris from ulcerating surfaces, and so also does enzymol, a proteolytic digestive agent which should be used diluted with an equal amount of water. In spite of occasional reports in favor of thuja, arsenic, and other drugs, we know of no remedy which limits the development of malignant disease in this situation. In cases which are not operated on, the physician is finally reduced to the necessity of administering morphine hypodermically, to render the patient's last days endurable. The application of agents that produce local ischæmia—such, for example, as adrenalin—may palliate, but nothing more.

Operative interference may take place either by way of the natural channels or externally. Endo-laryngeal methods have met with gratifying success in the hands of a very few men, but at the present time these methods are not considered preferable to the others. The improved results which have been secured by the adoption of external methods of operating upon the larynx not only justify the wisdom of this step, but stamp it as the only safe course to pursue. Of the external operations we have the choice between thyrotomy and partial or complete laryngectomy. The latter operation is described farther on in the present volume.

The Operation of Thyrotomy.—The operation of thyrotomy, called also "laryngo-fissure," consists in splitting the thyroid cartilage in the median line and turning back its two halves so as to afford direct access to the contents of the laryngeal box. It is indicated when endo-laryngeal methods either are impossible or bid fair to be unsatisfactory. The chief indication for its performance are: (1) removal of broad sessile benign growths (such as multiple papillomata) or malignant growths; (2) removal of impacted foreign bodies; (3) removal of cicatricial bands and adhesions; and (4) removal of necrosed cartilage. It may be added that direct inspection of the laryngeal interior, in case of malignant growths, invariably reveals a greater extent of infiltration than is suggested by the image seen in the mirror. A thyrotomy may easily be converted into a partial or complete laryngectomy should such a formidable procedure be deemed necessary. (For a detailed account of the operation of thyrotomy the reader is referred to the article on "Surgery of the Neck," in Vol. VI.)

After the operation there are two dangers which should be guarded against: 1st, septic infection of the wound, and 2d, septic inflammation of the lung from the entrance of food, blood, or secretions. To avoid these accidents the rules given by Butlin should be carefully observed. The tracheal tube should be introduced immediately after the operation. The gauze covering the wound should be changed as soon as it is in the least degree soiled. Insufflations of iodoform should be made from time to time during the first day or two. The patient should lie toward one side and with a very low pillow, so that drainage will naturally be toward the exterior. No food should be given for twenty-four hours. The patient may then be allowed to swallow a little sterile fluid. If it returns through the wound, rectal feeding should be begun.

As to the integrity of the voice, the ultimate result is somewhat uncertain, depending on the extent and location of the morbid tissue in each individual case.

The "starvation" operation—that is, the checking of the growth of a tumor by the ligation of the arteries supplying the area in which it is located—has not been attended, so far as we know, with any decisively favorable results in this situation.

The work of Semon, Butlin, and other surgeons has given the operation of thyrotomy, for the removal of cancerous growths in the larynx, a great impetus in recent years. It should be undertaken early. In fact, the whole question of operative intervention is conditioned on early recognition of the nature of a suspicious growth. If thyrotomy is done, not only should the growth itself be removed but a section of surrounding healthy tissue should also be removed. The prospect of a good voice after the operation is fair; the death-rate from the operation itself is extremely low; and the likelihood of recurrence is reduced to a minimum. von Bruns has recently reported statistics of 114 cases of thyrotomy performed in the last 16 years for the relief of cancer of the larynx. In this series the death-rate was only 9 per cent, recurrences took place in 22 per cent, while a cure that lasted a year or more was recorded in 48 per cent. von Bruns contrasts these results with a series of total extirpations of the larynx performed between 1873 and 1894. In the latter series the death-rate was 44 per cent, recurrence took place in 32 per cent, and a cure that lasted for one year or more was effected in only 12 per cent. He attributes the improvement in part to earlier diagnosis and in part to the fact that the laryngectomy has been only partial. It is hardly fair, perhaps, to compare early laryngectomies with later thyrotomies, but Glueck, whose success in the former operation has been most remarkable, has had at least one series of twenty-four consecutive total laryngectomies without a single death from operation. Butlin's suggestion, to do an exploratory laryngo-fissure and then to determine what the subsequent course shall be by the findings in the area thus exposed, is without doubt the most sensible proposition.

V. INTUBATION.

Intubation, which had been tried by a number of clinicians at various times, was made a practical operation by the late Joseph O'Dwyer, of New York. So careful was his study of the question and so thorough his appreciation of all the pathological and mechanical problems involved that very little of essential value, beyond the expansion of the field of utility of the procedure, has been added to his original communications on the subject.

Indications.—The operation is performed more often for the relief of diphtheritic stenosis than for any other object. With modified tubes, however, it is applicable in conditions of chronic stenosis due to such causes as post-typhoid ulceration, syphilitic contraction, outlying growths, trauma, inflammatory spasm, and some forms of laryngeal paralysis.

Equipment.—Herewith are figured many of the familiar intubation instruments (Figs. 424–429). They consist of a scale by means of which the size of

Fig. 424.

Fig. 425.

Fig. 424.—O'Dwyer Intubation Tubes. I, Tube suitable for use when granulations are present; II, lateral view of the tube ordinarily used; III, anterior view of the same.

Fig. 425.—Special Tube for Use in the Treatment of Certain Conditions of the Larynx. *a*, Side view of the tube; *b*, front view of "special" tube showing enlargement near its middle.

tube required for a child of a given age may be determined, a mouth-gag, an introducer, an extractor, and a set of tubes. The tubes may be made of metal or of hard rubber with a metallic lining. The metal tubes have the disadvantage of allowing the incrustation of salts from secretions, but this difficulty is practically removed by plating the tubes with gold.

Fig. 426.—Mouth Gag.

The Operation.—In diphtheria, the child should be wrapped in a sheet or blanket (only the head being exposed) and firmly held by an assistant who places the patient's legs between his own and holds the latter's back firmly against his own chest. Another assistant holds the child's head firmly in the median line. The gag (Fig. 426) is placed between the patient's molar teeth and the operator hooks forward the epiglottis with the forefinger of his left hand. With the instrument held in his right hand he next passes the introducer, with the tube attached and threaded with braided silk, into the child's mouth, the handle of the introducer being held at first well down on the patient's chest and the thread being loosely wound around the operator's little finger. As soon as the distal end of the tube reaches the larynx the handle of the tube is abruptly turned so as to render the tube itself vertical. When in this position the tube is passed down into the larynx so that the flange on its upper extremity rests on the glottic margin. The introducer is disengaged by forward pressure upon the device on the handle of the instrument, and the tube is pressed down into position by the finger which is still in the throat. The thread loop is passed over the patient's ear and the gag is removed, the patient's arms still being confined. As soon as air

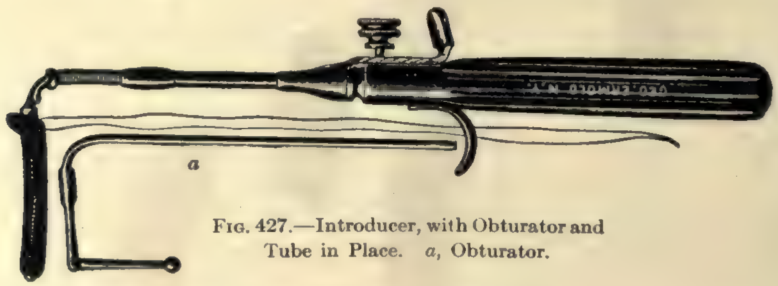

FIG. 427.—Introducer, with Obturator and Tube in Place. *a*, Obturator.

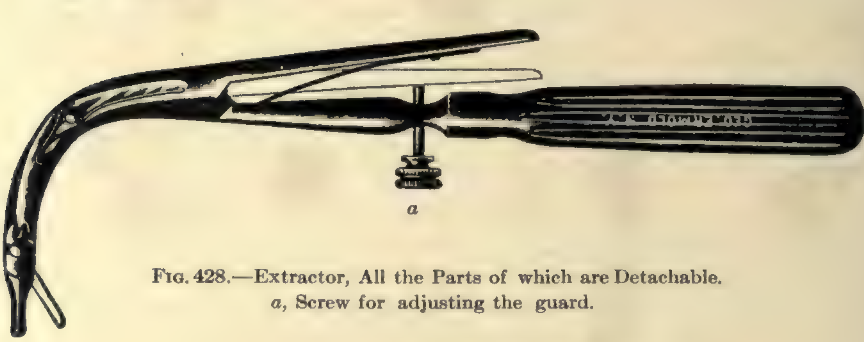

FIG. 428.—Extractor, All the Parts of which are Detachable. *a*, Screw for adjusting the guard.

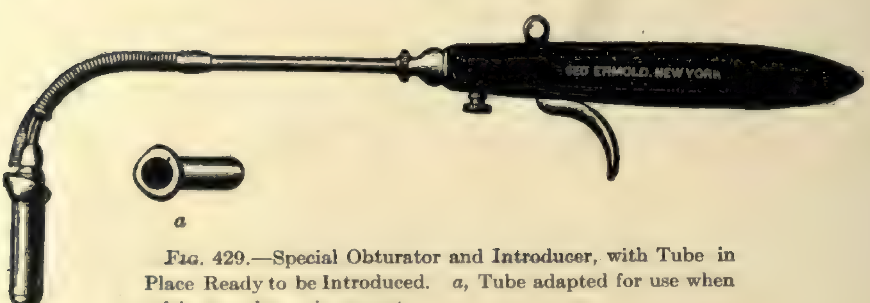

FIG. 429.—Special Obturator and Introducer, with Tube in Place Ready to be Introduced. *a*, Tube adapted for use when a false membrane is present.

begins to pass there is heard a peculiar coughing which is characteristic of a successful introduction of the tube. Breathing at once becomes easy, color improves, and the child often falls asleep immediately. If the tube has been passed into the gullet, there is no relief to the dyspnœa and the vermicular action of the gullet draws the tube downward, as is evidenced by the gradual shortening of the thread loop by means of which the tube can at once be withdrawn and its proper insertion be again undertaken. If satisfied that the tube is properly placed, the operator again inserts the gag, places the left index finger on the tube to hold it in place, cuts the loop, and withdraws the thread. In these manipulations it is important that one should work in the exact median line, should handle the instruments gently so as to avoid making a false passage, should keep the back of the left index finger in contact with the patient's posterior pharyngeal wall, making it, as it were, a continuation of the latter, and should make the sudden turn of the introducer in such a manner as to bring the tube to an exact vertical position. When it is desired to remove the tube the gag is inserted as before, the surgeon's left index finger is placed on the top of the tube, care being taken not to press it downward, the extractor is introduced into its lumen, the latter's jaws are then opened, and the tube is removed by a movement the reverse of that employed when it was introduced. During these manœuvres respiration is necessarily suspended, but neither the introduction nor the withdrawal of the tube should occupy more than fifteen seconds.

Fig. 430.—Diagram Showing the Mode of Introducing an O'Dwyer Intubation Tube. The tube is just engaged in the larynx.

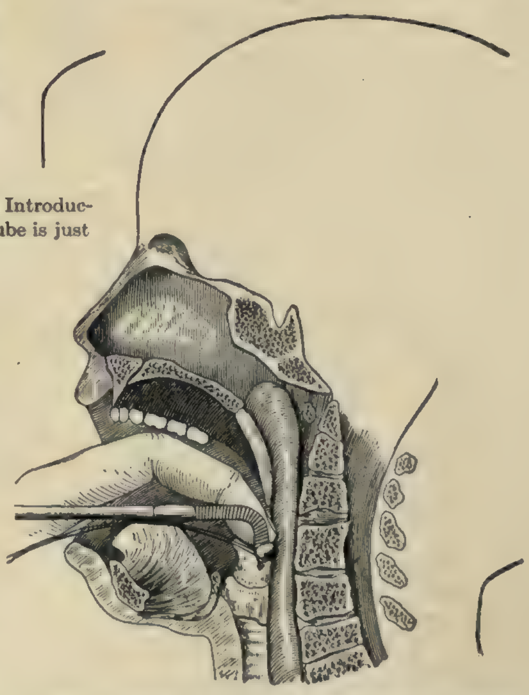

Fig. 431.—Second Stage of the Operation of Introducing an O'Dwyer Intubation Tube. The diagram shows the shaft of the introducer lying flat on the tongue and the tube passed already a considerable distance into the larynx.

If for any untoward cause the tube should be swallowed it will probably pass through the bowels without difficulty. If it is coughed out it should be re-inserted, provided the symptoms show that it is still needed.

In any event, it is well to remove it at the end of four or five days, even if its immediate re-insertion is called for.

The intubated child is necessarily restricted to fluid food. This may be drawn up through a tube, the containing vessel being held at a lower level than the child's head. Older children can sometimes swallow best by lying on the back with the head lowered so that the pharynx is below the trunk level. Rectal enemata and nasal feeding afford other means of nourishment.

The advantages of this operation over tracheotomy are the following:—It is simple and only slightly painful, does not produce shock, does not require the making of a wound, allows of more effectual coughing, and is not apt to be followed by pneumonia when the air passes through the natural channels, diseased though they be. Difficulties may arise from pushing loose membrane into the trachea. If this should happen withdraw the tube and allow the membrane to be coughed out; then re-insert. The tube may become blocked by membrane after it has been inserted. Tube and membrane are then generally coughed out together. Supratubal œdema is improbable, as the tube rests on the ary-epiglottic folds. Ulceration from the presence of the tube is generally avoided by choosing one of the right size and calibre.

FIG. 432.—Third Stage of the Operation of Introducing an O'Dwyer Intubation Tube. The diagram shows the surgeon's left forefinger pushing the tube down into place, while at the same time the obturator is being withdrawn from the mouth.

In cases of intubation for chronic stenosis, somewhat larger tubes may be necessary, and it is sometimes difficult to keep them in position. To obviate this difficulty Rogers,* of New York, has devised "plugged" and "clamped" tubes. A "plugged" tube (Fig. 433) is "one fitted with a plug made to screw accurately into the anterior wall of a normal or special tube through a tracheal fistula. The plug is perforated at its inner end by a hole which exactly corresponds in size with the lumen of the tube. The plug is provided with a retaining pin which,

* J. Rogers and D. B. Delavan: "Treatment of Chronic Laryngeal and Tracheal Stenosis." Trans. Amer. Laryngol. Assoc., 1905.

when the plug is in place, prevents it from rotating and so obstructing in the slightest way the lumen of the tube. By previous measurement the tube has a hole bored in its anterior wall, which hole, when the tube is inserted, lies opposite the tracheal fistula. Into this hole the plug is then screwed and "pinned" at right angles to the tube. By a "clamped" tube is meant "one fitted with

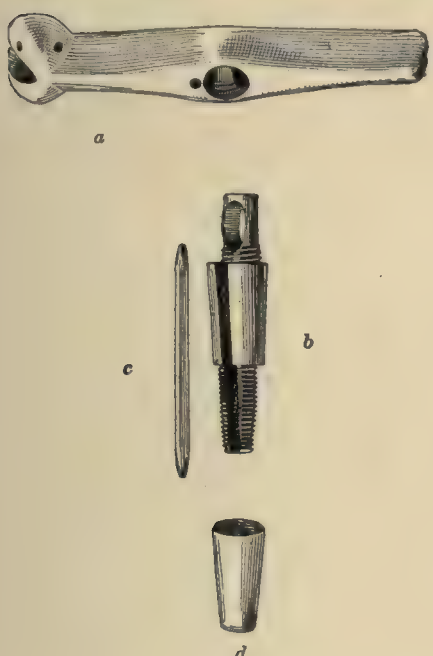

FIG. 433.

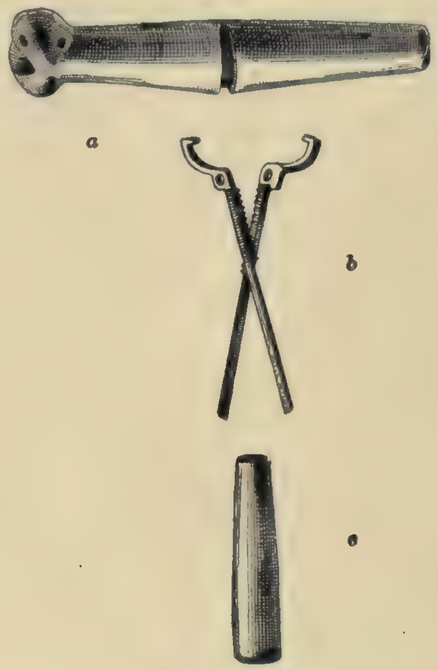

FIG. 434.

FIG. 433.—Plugged Tube, for Use in the Treatment of Chronic Laryngeal and Tracheal Stenosis; a Modification of the O'Dwyer Tube. (After Rogers and Delavan.) *a*, "Plugged" tube with perforation in its anterior wall; *b*, "plug" with its inner ond perforated to correspond with the lumen of the tube; *c*, pin to prevent the plug from rotating and obstructing the lumen of the tube; *d*, cap to hold the pin in the groove on the plug and in the hole into which it fits in the frame of the tube.

FIG. 434.—Clamped Tube, for Use in the Treatment of Chronic Laryngeal and Tracheal Stenosis. (After Rogers and Delavan.) *a*, "Clamped" tube with enlarged neck; *b*, clamp to insert through the fistula in the trachea into the groove on the front and sides of the tube; *c*, cap to hold the clamp in position by screwing over the shanks.

a detachable pair of metal clamps made on the principle of an obstetric forceps. In the sides of the tube are cut grooves which, when the instrument is in place, lie at the level of the tracheal fistula. Through this the clamps are made to grasp the tube, and are then held in place by a collar screwed down around them until the collar touches the tube." Both these tubes are guaranties against auto-extubation and keep the tracheal fistula patent.

VI. NEUROSES OF THE LARYNX.

Laryngeal neuroses are (1) sensory and (2) motor. The former include anæsthesia, hyperæsthesia, paræsthesia, and neuralgia; the latter, various forms of spasm and paralytic conditions.

Anæsthesia.—Anæsthesia may be due to impairment of function of the superior laryngeal nerve from bulbar or more diffused lesions in the nerve centre, as in the medulla, in locomotor ataxia; or it may come from a local neuritis due to diphtheria, influenza, etc. It occurs in minor degrees in long-continued catarrhal states and in syphilis, and is a prominent feature in many cases of hysteria. It is evidenced by the absence of cough and reflex phenomena. In the severe forms there is danger of choking from accumulation of secretions, food, etc. Many cases are cured by general nerve tonics. The intralaryngeal application of the faradic brush is a measure of much value. It should be used several times daily, one electrode being applied over the course of the superior laryngeal nerve and the other electrode being applied outside the organ or in the shape of a broad flat sponge on the nape of the neck. The impaction of a morsel of food calls for removal by forceps or by tracheotomy.

Hyperæsthesia.—Hyperæsthesia of the laryngeal mucous membrane arises from all sorts of inflammations, simple and specific; it may also be a reflex manifestation from lesions elsewhere and often appears in the course of rheumatism, gout, and cancer. Its severity varies from a mere annoyance to an intense pain increased by attempts at speaking or swallowing. Treatment obviously must be directed to removal of the exciting cause.

Paræsthesia.—Paræsthesia includes almost an infinite variety of abnormal sensations. The most common are the sensation of a foreign body being present, tickling, and a desire to swallow. Often the feeling is a reflex phenomenon due to some abnormal condition on the back of the tongue—such, for example, as enlargement of the lingual tonsil, dilatation of the lingual veins, small ulcers caused by the lodgment of foreign bodies which have been swallowed later, etc. In the case of the latter, sedative inhalations and time will relieve the symptoms. The lingual tonsils may be reduced by means of some cutting instrument or the galvano-cautery. The action of the latter can be very definitely limited. Caution is advised with reference to the production of too much scar tissue in this locality. Dilated veins can be seared with the cautery at a dull-red heat.

Neuralgia.—Neuralgia may arise from acute inflammations, gout, rheumatism, anæmia, malaria, etc. Each suggests its own treatment. Such cases fall under the domain of the physician rather than under that of the surgeon.

Motor neuroses may be either (1) spasmodic or (2) paralytic.

Spasm of the Larynx.—Spasm of the larynx occurs frequently in children in the course of ordinary catarrhal inflammation, causing the familiar "croupy" condition with its stridulous cough and voice. Other causes of spasm in children are local irritation, as from lodgment of food particles, prolonged crying, exposure to cold, and pertussis. The spasm may also be of a reflex character, dependent upon intestinal irritation. The child may awake in the middle of the night with a sudden choking. The condition generally passes off as soon as the activity of the local glands is re-established. Emetics may help to clear out any accumulated tenacious secretion. Some authorities deny that any actual spasm exists under these circumstances and claim just as good results from simple derivative measures such as mustard baths. Inhalations, fomentations, amyl nitrite, etc., have all been recommended. In some instances, particularly those unattended with marked manifestations of inflammation, the passage of a soft-rubber male catheter or of a female silver catheter will afford relief. Intubation and tracheotomy are also at one's disposal, but such radical measures are in this simple form of the malady rarely called for.

In croupous conditions—that is, in those due to the presence of a false membrane not necessarily produced by the Klebs-Loeffler bacilli—the mechanical conditions are the same as in diphtheria and are to be treated accordingly, so far at least as mechanical relief of the dyspnœa is concerned.

In children the spasmodic element is confined practically to the constrictor muscles, but in adults the dilators may also be affected; the former, however, predominating. Among the causes (in adults) may be mentioned the following: the entrance of food and drink, the presence of foreign bodies, intralaryngeal manipulations, reflex influences from the genital and alimentary tracts, pressure on the nerves supplying the part, crises in tabes and other central nervous lesions, syphilis, and tuberculosis. In the two latter the spasmodic stage follows on a preceding infiltration, and in this class of cases, therefore, we are forewarned. The attacks occur more often at night. Association with other symptoms will generally determine the nature of the exciting cause. Rarely, the crisis is an initial symptom of tabes, and such cases may be for a while puzzling. The patient should be placed upon a hygienic regimen, and an endeavor made to remove the cause. If cold bathing is undertaken, care should be exercised at the outset not to have the water too cold. Emergency cases may call for intubation with adult tubes or, rarely, for tracheotomy.

Paralytic Conditions.—With reference to conditions of paralysis it may be said that treatment has reference mainly to removal of the cause and belongs therefore more naturally in the domain of the physician. In bilateral paralysis of the abductors we have a condition which requires from the start most careful watching. In some cases of rapid development the wearing of a tracheotomy tube has been followed by recovery, but it is evident that in these cases the paralysis was due to some cause not necessarily irremediable. If the condition has lasted several months, muscular degeneration and possible changes in the crico-arytenoid joint preclude the possibility of recovery. Under such conditions a tube becomes a constant necessity.

Attention may also be called to the use of an intubation tube in those cases in which, from the etiological standpoint, a cure is possible. Some years ago Krause suggested the possibility of excising the cords with a view to furnishing a permanent patency of the air tract at this point and of thus dispensing altogether with tubes. This has been successfully done and is to be included among the procedures possible in this condition.

VII. MALFORMATIONS AND WOUNDS OF THE TRACHEA.—NEW GROWTHS IN THE TRACHEA.

Malformations of the Trachea.—The trachea possesses some peculiarities which vary according to age. Thus, as Quain points out, in the fœtus it is flattened before and behind, its anterior surface being even somewhat depressed. The ends of the cartilages touch, and the sides of the tube, which at this period of development contains only mucus, are in contact. Respiration opens it somewhat, but it still remains flattened in front and becomes convex only at a later period. The larynx in the infant is relatively high and consequently the cervical portion of the air tube (the trachea) is somewhat longer than in the adult. The higher position of the manubrium sterni somewhat lessens this apparent length. The bifurcation is about one vertebra higher in the infant than in the adult. At 6 months, the trachea will admit a tube of 4 mm. calibre, at 2 years one of 5 mm., and at 6 years one of 6 or 7 mm. Ossification of the cartilages begins at about the fortieth year in the male and the sixtieth in the female.

Various abnormal anatomical relations have been from time to time reported. Thus, the axis of the tube does not always coincide with the median line of the body. The surgical significance of this fact is obvious. Low down on the left wall a pulsation is often noted, due to the impact of the subjacent pulmonary artery which lies first in front of, and then above the left bronchus. The deviation from the normal axis may suggest some compression from without. To distinguish this latter condition from one due to actual disease, we have the presence, in disease, of a certain amount of congestion of the parts, whereas in the mere malposition this would be lacking. By changing the position of the patient or the angle of the examining mirror it will generally be possible to clear up all uncertainty. Finally, the symptom of dyspnœa is lacking, although the trachea may seem to be narrowed. An hour-glass contraction has been found in the middle of the trachea, the membranous portion being absent at this point. Dilatations and pouches have also been observed. The mode of their formation is considered under the head of Laryngocele. Felix Semon has reported one case in which the trachea seemed bent from right to left just below the larynx, and again in the reverse direction lower down, so that, at the site where one would have expected to see the bifurcation, there seemed to be on the outside some influence which pressed the trachea inward.

Wounds of the Trachea.—The trachea may be injured by any kind of accident. There may be simply a contusion, or the cartilages may be fractured. Years ago Mr. Thomas R. Bryant reported one case in which, following a crush, the trachea was found to be completely divided subcutaneously without there being any external bruise to denote the severity of the injury. The distance separating the two ends of the tube, at the point where it was divided, was found to be about an inch and a half.

SYMPTOMS.—In all these injuries there will be present, from the very beginning, more or less dyspnœa with its attendant features. Blood may flow into the trachea and cause cough, at first, and later a slowly or rapidly developing asphyxia. The external appearances will vary according to the nature of the wounding agent. There will be more or less bleeding from the wound, and possibly there may be some emphysema of the neighborhood. At a still later period the dangers to be looked for are septic inflammation of the wound and adjacent tissues and pneumonia.

TREATMENT.—Treatment calls, first, for the arrest of any bleeding that may be taking place. If it appear to consist of a general venous oozing, a large silver tube may be introduced into the trachea and the wound temporarily plugged around it. If the trachea has been cut entirely across, a suture or two should be inserted on each side to prevent the separation of the parts, which otherwise, owing to the great motility of the larynx and upper end of the wind-pipe, would be sure to take place. The circumstances existing in each individual case will have to determine the question whether the external wound should be closed or left open. Closing the wound by means of sutures always involves the danger that clots may accumulate beneath the surface and cause suffocative symptoms. Proper facilities should be provided for drainage. If the wound is high up in the trachea, and the symptoms are of a threatening character, it will be advisable to perform a low tracheotomy. (See also the section on Cut-Throat, in the article on "Surgery of the Neck" in Vol. VI.)

New-Growths in the Trachea.—Tracheal tumors are uncommon as compared with those of the larynx. In Semon's collection of 10,000 cases of benign growths in this general region, tumors of the trachea were found only in the proportion of about 1 in a 100 cases. von Bruns found the proportion to be 7 tracheal tumors to 300 laryngeal growths, and Schmidt 3 to 748. This infrequency is doubtless due to the fact that the trachea has the passive function of an air conduit as compared with the complicated activity of the larynx.

The statistics of tracheal growths have recently been analyzed in an exhaustive paper by Theisen.* This author found records of 90 benign and 46

* Theisen, in Transactions of American Laryngological Association, 1906.

malignant tracheal growths. In addition to these there were reports of other cases which, owing to the insufficiency of the data published, Theisen thought it best to exclude altogether. The number given is classified as follows:—Papilloma, 25; fibroma, including fibrous polypus, 24; chondroma and chondro-osteoma, 17; intratracheal struma, 10; adenoma, 7; lipoma, 3; lymphoma, 2; and amyloid growth, 2. These comprise all the benign growths. The malignant growths were divided as follows: Carcinoma, 28; sarcoma, 18.

The report in question furnishes the following further facts of interest to the surgeon: The middle third of the trachea appears to be the portion least often involved. Papilloma generally occurs in the trachea in connection with a growth of the same nature in the larynx, but there may be no direct connection between the two. The majority of cases have been found in children. In twenty-five per cent of these cases the growth was considered congenital, as the symptoms came on immediately after birth. In less than one-third of the cases the growth was confined to the trachea alone. The favorite tracheal site appears to be the upper portion of the anterior wall.—In the case of the fibromata it was found that 15 were pedunculated and 9 sessile. Most of them occurred at the middle period of life. No predilection was noted for any special portion of the trachea.—Only a single instance of a pure ecchondroma was found; it was located at the fifth tracheal ring.—There were, as will be observed, 10 cases of struma. Paltauf's theory is that this form of growth originates, not in intra-uterine but in extra-uterine life, by penetration of the gland tissue between the thyroid cartilage and the first tracheal ring, between the thyroid and cricoid cartilages, and sometimes through the interstitial tracheal membrane itself. According to this theory, therefore, tracheal struma is merely a direct extension of an enlarged thyroid gland. Of the 10 cases here referred to, all but 1 occurred in the lower larynx and upper trachea, the deposits being attached to the lateral and posterior walls. The age limits were 15 and 40 years. Goitre was present in all but 2 cases. Three occurred in males and 7 in girls and young adult women.—Adenomata appear as hypertrophies of the mucous glands on the posterior wall of the trachea.—Carcinoma is generally of the medullary variety. Men are twice as frequently affected as women. The cancerous mass may occur as a distinct tumor or as a diffused infiltration. The posterior wall of the trachea is the locality most frequently affected. Here as elsewhere no special facts are known as to the exciting cause of the new-growth.

Symptoms.—The symptoms of tracheal tumors are often surprisingly few in number and rather insignificant as regards their severity. On autopsy there have been found large growths which during the patient's lifetime gave no symptoms whatever. The natural expression of impaired tracheal calibre is difficulty in breathing, amounting in some cases to actual suffocative attacks. Somewhat curiously, such symptoms are often intermittent, although the cause remains constant. A pedunculated growth may act as a floating valve and cause either inspiratory or expiratory dyspnœa according to its movements. Hoarseness without dyspnœa has been noted in some cases of pedunculated growths in which the pedicle was long enough to allow the growth to be carried up to the level of the glottis. Laryngeal changes may arise from the pressure of the growth on the recurrent nerves. Gerhardt declares that tracheal obstruction inclines the patient to bend the head forward, while obstruction in the larynx leads to a bending backward. Secondary changes may appear in the lungs from atelectasis, bronchiectasis, and various simple or purulent inflammations.

Diagnosis.—Assuming that the symptoms suggest some interference with the integrity of the tracheal calibre, we should first determine whether the tube is being pressed on from without or obstructed from within. The former may result from aneurism or from any kind of mediastinal growth. The latter may be due to the presence of a tumor or a foreign body or to stricture. The vertical position of the growth obviously conditions the ease with which it may be located. The ordinary laryngeal mirror will give a view of any growth that may be located in the upper part of the tracheal tube. Laryngoscopy may, if the necessity arise, be made under anæsthesia. At times, by placing the patient in the position suggested by Rose and by employing an epiglottis-lifter, a satisfactory view of the growth may be obtained. Other diagnostic methods are autoscopy, with the Kirstein spatula, and radiography. Finally, we have at our command the more recent method of tracheoscopy, which is considered under the heading of Foreign Bodies. (See page 906.)

As to the precise nature of the growth it may be said that the question can be settled by the same means as those which are employed in determining the character of tumors in general. The coexistence of papilloma in the larynx warrants the assumption that the tracheal growth is of the same character. Fibroma is the most favorable variety of benign growth. Sarcoma is generally smooth and grows slowly. Carcinoma is more apt to be ulcerated, grows faster, and merges insensibly into the surrounding parts.

Prognosis.—The prognosis is unfavorable unless operative intervention is possible. Death may result from slow suffocation, from metastatic deposits in other organs, or from septic pneumonia.

Treatment.—As soon as any alarming dyspnœa has developed, tracheotomy should be performed and the patient should habitually wear a tube. The degree of relief which this procedure will afford depends naturally on the site of the growth. Unless the tube can be inserted below it, not much benefit can be expected. In one case a malignant growth had so invaded the trachea that the insertion of a tube was impossible. Preparations should therefore be made at the time of the operation for radical removal of the growth. In the case of a benign tumor located high up in the trachea, removal by endolaryngeal methods is often feasible, but the instruments employed should have an extra length. Laryngo-fissure or tracheo-fissure will afford direct access to the growth.

Theisen found that, in 14 cases in which a benign growth of the trachea had been removed by operation, 10 recovered, while out of 12 similar cases upon which no operation had been performed the same number died. In one instance the trachea was resected and the patient subsequently lived six years. Endotracheal methods are entirely unsatisfactory in dealing with malignant growths. After tracheotomy tubes have been passed down to the mass its removal may be effected by various instruments.

VIII. TRACHEOTOMY AND ALLIED OPERATIONS.—FOREIGN BODIES IN THE TRACHEA AND BRONCHI.—TRACHEOSCOPY, BRONCHOSCOPY.

Tracheotomy and Allied Operations.—The object of this class of operations is to admit air into the lungs when its entrance through the natural channel is impossible owing to some obstruction above, or in the larynx, or in the upper part of the trachea. The obstruction may arise in the passages themselves or be caused by pressure exerted on them by abnormalities in adjacent parts. Exact conditions in a given case determine the choice of operation. In general, where the obstruction is located above the larynx, laryngotomy is preferable. At the same time it should be remembered that before puberty the small size of the crico-thyroid membrane may render the insertion of a tube at this spot difficult. If the obstruction (a tumor or foreign body) is in the larynx, tracheotomy or laryngo-tracheotomy is preferable. It is obvious that if a tracheotomy is performed the incision may be extended above or below, as the case may require. For all these operations, chloroform is the preferable anæsthetic. Most of the prophylactic operations (see further on) can be done with the aid of cocaine or other local anæsthetic agent. None whatever is required when the operation is one of emergency in a patient profoundly asphyxiated.

The operation of tracheotomy may be required under the following circumstances:—As a prophylactic measure, to prevent blood and discharges from entering the lungs; for the removal of foreign bodies, including false membranes, clots, etc.; for the relief of a threatened asphyxia due to spasm of the glottis from any cause, to some form of laryngeal paralysis, to stenosis caused by cicatrices or by pressure from the outside, or to œdema of the glottis; for the purpose of placing the vocal cords at rest, as in tuberculosis and syphilis; for the removal of papillomata in children; and for the eradication of any form of neoplasm which directly encroaches on the lumen of the tube.

The expressions "high tracheotomy" and "low tracheotomy" have reference to the situations in which the incisions are made—whether above or below the thyroid isthmus, which generally crosses the third or fourth tracheal ring. Whatever may be the operation decided upon, the patient should lie flat on the back, with the shoulders drawn down and the head well extended. The anæsthetist, who has the patient's head under control, should be careful to keep it exactly in the median position, his guides being the point of the chin and the middle of the suprasternal notch. The surgeon, standing on the patient's right and stretching the skin with his thumb and finger on opposite sides of the trachea, makes a free median incision from one and one half to two inches long, avoiding, if possible, any visible vein. Retraction of the parts thus severed reveals the space between the sterno-hyoid muscles. The deep fascia is next divided, and, the muscles having been retracted, the thyroid isthmus comes into view. The fascia which binds it to the trachea is freely divided in a transverse direction, thus laying bare the upper tracheal ring. With the handle of the scalpel the surgeon bares the tracheal wall so as to expose the two or three rings just below the isthmus. In order that the trachea may be properly steadied a hook is caught in its substance and given to an attendant to hold. The blade of the scalpel, held not more than three-quarters of an inch from the point, is thrust through the tracheal wall and carried, from below upward, for the distance of two or three rings, the cricoid cartilage being severed if necessary. A bivalve instrument is now inserted, the separation of its blades affording entrance for whatever form of tube may be preferred. As soon as the wind-pipe is opened, air rushes in and cough ensues with the expulsion of tracheal contents. If the latter are especially abundant it is better to hold the slit open for a few minutes before inserting the tube. Foreign bodies are often expelled at once through the opening.

If, for any reason, section through the thyroid isthmus is required, it is divided in the median line between clamps, and ligatures are then placed around the cut ends of the two halves.

If a low tracheotomy is to be done, the depth of the trachea conditions the length of the incision. In children the latter may extend from just below the cricoid to the suprasternal notch. The earlier steps are in general the same as those just described, but we should be on the lookout for the branch vein which joins the two anterior jugulars. The separation of the sterno-hyoid muscles, which diverge below, reveals the sterno-thyroid muscles which converge at that level. The fascia that separates these two muscles is now divided, and the trachea is laid bare. The inferior thyroid veins will be encountered and should be ligated and divided between the ligatures. The trachea is then opened in the manner already described.

If tracheotomy is done at a time of election it is a comparatively simple procedure. In emergencies and in patients with fat necks, it is often quite another matter. Surgeons who, in the haste and excitement of the moment, have missed the anatomical landmarks, have wounded the innominate and carotid arteries and have penetrated through the trachea into the œsophagus and even into the spine. One of the annoyances of the operation is bleeding from the thyroid veins. Only the largest of these need be ligated, for it is probable, especially in cases of asphyxia, that the opening of the trachea and the entrance of air will check the flow from the smaller vessels. Other possible sources of bleeding are these: occasionally a thyroidea ima artery, on the front wall of the trachea (it is usually given off from the innominate); the innominate itself, which may cross the trachea above the sternum instead of (as is usual) below; and a right carotid artery that has been given off from the aorta. In exceptional cases trouble may be experienced in operations from the fact that the thymus and thyroid bodies have become united. Occasionally it will be found necessary to employ artificial respiration for a few minutes after the tube has been inserted. Mechanical removal of tracheal contents may be called for. Tubes should always be held in place by tapes passed around the neck and covered by a thin layer of aseptic gauze so arranged that it can be instantly thrown back. The inner tube should be removed at intervals, disinfected, and replaced. Some surgeons prefer to leave a loose loop of suture material in each lip of the wound so that if the tube suddenly becomes blocked the wound can be immediately held widely open. There is value also in the suggestion that tubes of different lengths should be at hand, in order that by substituting one of these, from time to time, for the tube already in place, the pressure of the lower end shall not always be exerted on the same area. The tubes should fit somewhat closely. The frequency with which the tube should be removed, and a different one put in its place, varies according to the requirements of each individual case. Even in the case of a patient from whose larynx or trachea a foreign body has just been expelled or removed, it is advisable to keep the tube in position for a day or so in order to allow any inflammation that may be present to subside. In prophylactic operations the tube may be withdrawn at once. It should be corked for a while before withdrawal in order to make it evident that the patient can breathe naturally without it. Tracheotomy wounds generally heal without incident. A fistula calls for closure by a flap. The union which takes place between the rings is effected by means of fibrous tissue.

Complications.—The most common complications are bronchitis, pleurisy, or pneumonia. In connection with the wound we may have a cellulitis of the neck or a diphtheritic inflammation of the edges of the wound. Secondary hemorrhage occasionally occurs either from a blood-vessel in the wound or from a tracheal ulcer.

Laryngotomy.—In laryngotomy the incision made should be one inch in length and should have for its centre a point corresponding to the middle of the crico-thyroid membrane. The latter should be incised transversely, care being taken to avoid a small artery that runs across the membrane to the lower border of the cricoid cartilage, and into the opening there should be inserted a tube which is flattened from above downward. As a rule, but little hemorrhage follows the section of the crico-thyroid arteries which cross this space.

The landmark in this operation is the lower border of the thyroid cartilage. Laryngotomy is to be preferred, in adults, when the obstruction is above the rima glottidis, as in impaction of food, in the presence of a pharyngeal tumor, etc.

Foreign Bodies in the Trachea and Bronchi; Tracheoscopy; Bronchoscopy. —The subject of foreign bodies in the larynx is elsewhere considered (p. 871). As there stated, they are removed under direct inspection by aid of the laryngeal mirror and, in exceptional cases, by "laryngo-fissure" (thyrotomy). When, however, the foreign body is lodged in the trachea or in a bronchus we have a more difficult proposition with which to deal and one that requires a different method of procedure. The problem is still further complicated by the fact that we have a condition in which the immediate results may be either sudden death or practically no disturbance of the system whatever; a condition, also, in which diagnosis is not always easy.

We may consider briefly here what happens in case nothing is done toward removing the foreign body and what are the results under the old methods. Statistics on these points were carefully collected by J. O. Roe, in 1893.* "Of the 450 cases in which the foreign body was lodged in the trachea, it was removed by incision through the neck in 239, with 201 recoveries. Of these 222 were by tracheotomy, 9 by laryngo-tracheotomy (8 of which recovered), 7 by laryngotomy, and 1 by thyrotomy (all recoveries). Of the remaining 211 cases, in 58 no operation was performed, and there were but 2 recoveries; in 124 the foreign body was expelled spontaneously, with 112 recoveries; in 14 removal was effected by forceps, in 9 by inversion, in 2 by emesis, in 1 by the use of iodine, in 1 by a blow on the back (all recoveries). In 2 cases oil was used, 1 patient recovering. Thus, of 450 cases of foreign bodies in the trachea there were 343 recoveries (77 per cent) and 107 deaths." It was a common experience that as soon as the trachea was opened the body was spontaneously expelled.

An element of untrustworthiness (recognized by the compiler) attaches to these figures, for doubtless there have been innumerable cases of spontaneous expulsion which have never been placed on record. The admission or rejection of such cases affects the mortality percentage. The operative mortality in the past may, with some degree of fairness, be placed in the neighborhood of twenty per cent. An enormous step in advance was made when the principle of endoscopy was applied to the examination of the trachea and its ramifications. Direct inspection was substituted for blind groping in the dark. It is at once evident that the statistics collected during the last few years may be expected to present a much more favorable aspect. (These statistics are given on p. 913.)

Symptoms.—The symptoms of a foreign body in the trachea may be almost *nil.* If it is large there is immediate interference with respiration, and if it is very large the patient becomes rapidly asphyxiated. If the foreign body is movable

* Burnett's "System of Diseases of the Eye, Ear, Nose and Throat," 1893, vol. ii., p. 517.

it does not remain long in the trachea proper. While there, it may move to and fro in the air current, causing hurried breathing, cough, and glottic spasm. If it goes down into a bronchus these immediate symptoms may cease. There may be no dyspnœa, cough, or pain. In such cases the ultimate danger is infection, leading to local, and then to general sepsis. The virulence of the bacteria with which the object may have been covered at the moment when it entered the trachea will determine the extent and severity of the lesions which its presence occasions. The shape and size will also, though to a less extent, exert an influence upon the parts with which it lies in contact. Substances which disintegrate and those which are naturally irritating are more harmful than smooth, unirritating materials.

Prognosis.—The prognosis depends on the factors just enumerated, the vitality and general condition of the patient, and the possibility of prompt intervention.

Diagnosis.—The diagnosis may be made (1) by direct inspection. This is obviously applicable to only a very few cases, *viz.*, those in which the foreign body has become fixed in the tracheal mucosa, especially on the anterior wall. (2) By physical signs. If the body is relatively unirritating and so small as not entirely to shut off the air from a part of the lung of appreciable size, it may remain for a long time without causing symptoms. If, however, it injures the mucosa or if it was contaminated at the time of lodgment, so as to cause tissue changes, early symptoms will appear. The ear will detect an area over which the percussion note is resonant, as the lung here still contains air. But auscultation at once reveals the fact that no air is entering or escaping from this area. Later, with increased inflammation, we shall obtain the physical signs of bronchitis, broncho-pneumonia, abscess, or gangrene. (3) By aid of the Roentgen rays. While many substances, especially those of an inorganic nature, may be rendered visible by these rays, it will not do to place too much reliance on a negative finding, as not a few cases are recorded in which the rays showed nothing, but in which, nevertheless, the presence of a foreign body was afterward demonstrated.

The demonstration of the presence of a foreign body in the larynx or trachea by direct inspection brings us to the consideration of modern methods.

The names of Killian, of Freiburg, Germany, and his associates are prominently connected with investigations along this line. Profiting by the experience of others and particularly by the adoption of the principle of the Kirstein spatula, Killian succeeded, in 1897, in devising a tube which might be passed into the trachea, by way of the larynx, and through which it was found possible to remove a foreign body under direct inspection. He adapted the familiar principle of the œsophagoscope to the examination of the trachea and bronchi, demonstrating that it was possible to penetrate in a straight line into the air tubes without damaging them. In the operation, therefore, certain angles in the air passages are straightened out by stiff hollow instruments, through which the work of inspection and localization of foreign bodies is accomplished under direct observation and followed by removal with suitable forceps. The angles referred to are two: 1st, that between the buccal horizontal and the vertical tracheal axes, and 2d, the angle between the horizontal and vertical axes of the trachea itself. The overcoming of the first angle is accomplished by passing the tube through the mouth and larynx down into the trachea or

FIG. 435.—Killian's Upper Direct Tracheoscopy. (From the *Journal of Laryngology*, vol. xvii., 1902.)

bronchus. This is known as the "upper operation." (Fig. 435.) To overcome the second angle a tracheotomy is done and the tube is passed directly through the incision in the neck into the trachea. This is known as the "lower operation." (Fig. 436.)

Many minor modifications have been made in these operations, but their essential principles remain unaltered. Naturally, the "upper method" is preferred, as it avoids the operation of tracheotomy. Three instruments are required: 1st, the hollow tube; 2d, a suitable illumination; and 3d, an extracting instrument which will work through the tube. In general, the tubes flare somewhat at the top and are graduated so that the depth of penetration can be positively determined. If the trachea alone is to be investigated local anæsthesia generally suffices in adults. After the instrument has been inserted the tracheal mucosa can be cocainized through the tube. A strong solution (say, twenty-five per cent) is required for these purposes. If the patient is a child or a very nervous person, or if the bronchi are to be investigated, a general anæsthetic is necessary, the patient being placed, at the time of the examination, supine with the head over the edge of the table. If cocaine is employed, the upright position is possible. Clinical experience has shown that, if the

FIG. 436.—Killian's Lower Direct Bronchoscopy. (From the *Journal of Laryngology*, vol. xvii., 1902.)

surgeon possesses the requisite manipulative skill, the introduction of these tubes is perfectly practicable.

Killian calls attention to the advisability of thoroughly cocainizing the left pyriform sinus and the posterior cervical region. His directions are to "pass the tube past the left sinus, directing it with the finger while the patient's head is held backward. If he cannot recline his head sufficiently, give it a slight inclination toward the right side until the [upper end of the] tube is lodged in the left corner of the mouth."

Coolidge, of Boston, who has had much experience with the operation, gives the following directions for passing the tube:—"The tube is passed under direct inspection. This may be aided, especially when the longer tubes are used, by bringing the larynx into view with Kirstein's autoscope or Killian's tube spatula, and passing the autoscope through this. As the glottis is reached the patient

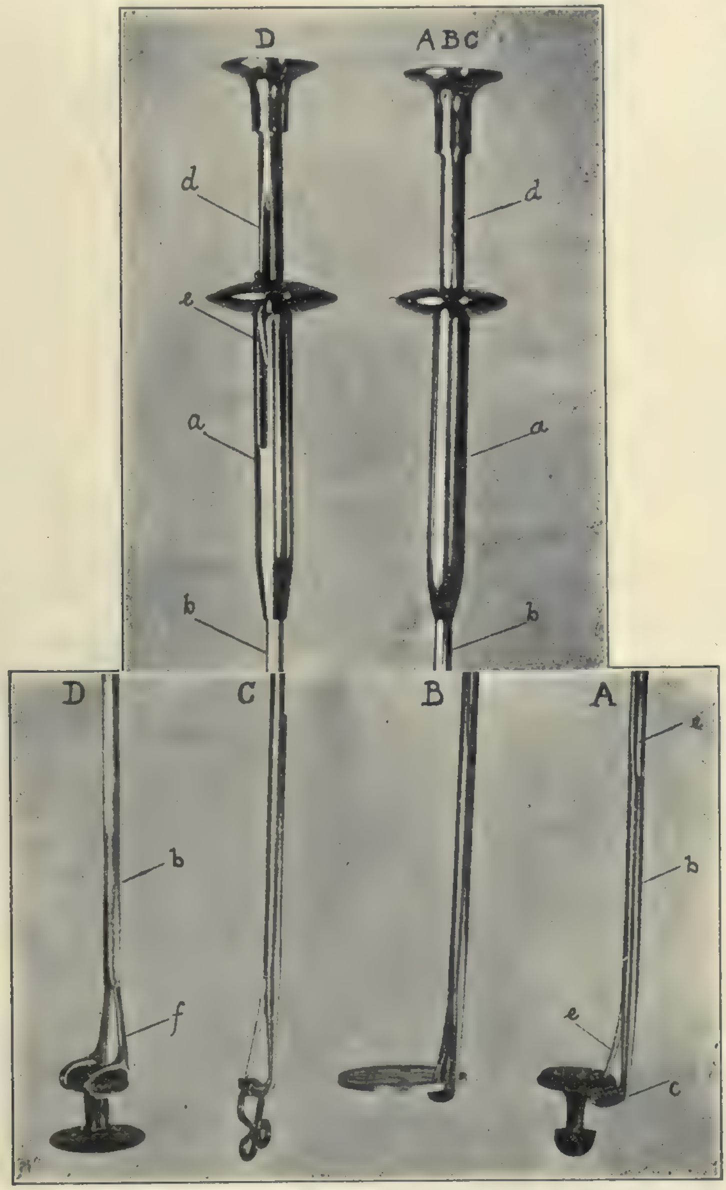

Fig. 437.—W. C. Morton's Instruments for Removing Foreign Bodies by Direct Bronchoscopy. (Dr. Morton's explanation of these instruments is given in the subjoined foot-note.*) Each of these instruments has a total length of about 14 inches. The upper and lower parts only are here figured. Natural size. (From the *Journal of Laryngology*, vol. xxi., 1906.)

* Explanation of William Cuthbert Morton's Instruments.—"To understand these instruments, let us look at any pair of tubular forceps. It consists of—(1) An outer part, one piece, made up of the outer part of the handle or grip, from which runs the tube, the tube carrying on

takes a deep breath, and the tube is passed between the cords and downward through the trachea to the bifurcation. In case it is necessary to enter one of the bronchi, the parts are cocainized and the operation is done under direct inspection. For the exploration of the bronchi the tube should be long enough to reach from the upper incisor teeth to the middle of the sternum—that is, in adults, from 30 to 35 cm. [12 to 14 in.] Killian has recently introduced an extension of a bronchoscope *in situ*, consisting of a section of tube of smaller calibre passed inside the first tube. A bronchus is capable of considerable movement or bringing into line by the bronchoscope, so that it may be searched through its primary or even secondary divisions. In this case a perforated tube must be used to maintain respiration through the other bronchus."

As to the diameter of the tubes, Killian advises, for male adults, 9 to 11 mm., for women 9 mm., and for children 7 mm.

It has been found that the best illumination comes from a forehead light.

its free end the forceps. (2) An inner part, made up of the inner part of the handle or grip, screwed into which is the rod, the rod carrying on its free end the ring to encircle the legs of the forceps. (3) The spring.

"The instrument being put together, pressure on the inner part of the grip forces the rod down through the tube and the ring down over the legs of the forceps, which are thus compelled to close. Now, instrument 'A' consists of—(1) An outer part, one piece, made up of (*a*) the outer part of the grip, from which runs (*b*) the tube, the tube carrying on its free end (which is solid) (*c*) the hook. At the point where the lumen of the tube ends the wall of the tube is perforated opposite to and not far from the hook. The hook is inserted into the end of the tube at a slightly obtuse angle, its near edge is toothed and only slightly concave. (2) An inner part, made up of (*d*) the inner part of the grip, screwed into which is (*e*) the rod, the rod being somewhat curved toward its point, and the point being sharp, so that the whole rod forms a long needle. (3) The spring.

"Pressure on the inner part of the grip forces the needle down through the tube, out of the end of which it passes through the perforation on the face of the tube in such a way that the point of the needle is driven to meet the toothed near edge of the hook some distance from the insertion of the hook into the tube, *i.e.*, toward the point of the hook. The curve in the end of the needle allows its point to come well toward the point of the hook; it also eases the work of the spring. Even in the tube the needle lies with the curve in the same plane with the hook, being kept in this position by the proper adjustment of the needle to the inner part of the grip, which again is adjusted to the outer part of the grip by means of a guide.

"The instrument can thus be manipulated like the ordinary hook until the hook (*c*) is in position on the far side of the plate of the stud. Then pressure on the inner part of the grip forces the point of the needle (*e*)—which so far has been lying concealed within the tube—against the near side of the plate, which is thus secured between the needle (*e*) and the hook (*c*). Within these limits the stud cannot move, otherwise its movement is free, and yet so perfectly is it under control that it can be drawn upward with any reasonable amount of force. Resistance against the opposite wall of the bronchus is diminished by the slight obtuse angling of the hook and by the slightness of the concavity of its toothed edge. Stability of the stud is favored by the needle not being too slender and by its not being long enough quite to reach the hook, as well as by the perforation being near the point of insertion of the hook. As this makes the passage forward of the needle more difficult, the end of the needle must be curved. Further, the hook must not be so long as to reach the neck of the stud.

"Instrument 'B' is like 'A,' except that the end of the needle is split into two points, which come down one on each side of the toothed edge of the hook, thus affording a very firm grasp.

"Instrument 'C' is like 'A' and 'B,' but the hook is deeply concave and the needle comes well forward to the point of the hook, which, however, it must not touch, so as not to nip the

More recently a small lamp has been attached to the distal end of the tube on the principle employed by Einhorn in his œsophagoscope. As a matter of safety the lamp, with its accompanying rod, may be in a separate compartment of the instrument.

Finally, the extracting instrument must necessarily be one that can be used through the tube. Forceps with varying shapes of blades meet the indications. Coolidge prefers an instrument in which the handles are at right angles to the central shaft carrying the blades. The barrel or tube surrounding the shaft is pushed down upon and closes the blades. Consequently the latter do not draw away from the foreign body at the moment of seizure. If secretion accumulates it must be mopped away with cotton carriers or removed with the suction apparatus of Killian. Coughing may be stopped by increasing the degree of anæsthesia, local or general.

For the removal of flat objects, such as small studs, buttons, etc., W. C. Morton has devised an ingenious instrument which is here figured. (Fig. 437.) It is a tubular forceps, and the author notes that in all such instruments there are but three essential parts—1st, an outer piece made up of the outer part of the handle or grip from which runs the tube carrying the forceps on its free

mucosa. A stud can be fairly grasped by the neck, and any such foreign body as the eye of a 'hook and eye' perfectly secured.

"Instrument 'D' [lower figure], a fenestrated hook-shaped forceps for grasping the head of a stud, etc., the hook shape admitting of better oversight of the blades of the forceps, while fenestration allows gracility of build.

"The above forceps is fitted with an 'inverted grip' [D, in the upper figure], which suits any other tubular forceps equally well, and consists of—(1) An outer part, made up of (*a*) the outer part of the grip, a piece by itself, with a longitudinal slit, and with a hole into which (*e*) the rod is screwed; (*b*) the tube, which, with (*d*) the inner part of the grip, forms one piece. (2) An inner part, made up of (*d*) the inner part of the grip which with (*b*) the tube forms one piece; (*e*) the rod with a thread at one end to be screwed into (*a*) the outer part of the grip; (*f*) [in D of the lower figure] the forceps at the end of (*e*) [in D of the upper figure] the rod, with which they form one piece. (3) The spring.

"Take the piece made up of (*d*) the inner part of the grip and (*b*) the tube. Slip (3) the spring over (*b*) the tube up to (*d*) the inner part of the grip. Then slip (*a*) the outer part of the grip over (*b*) the tube till it rests against (3) the spring. Pass (*e*) the rod up (*b*) the tube until it reaches the level of (*a*) the outer part of the grip. Here (*b*) the tube has a slit on one side corresponding to the slit in the outer part of the grip, through which slits (*e*) the rod is so guided that its threaded end slips into the hole in (*a*) the outer part of the grip, into which by a few turns it is screwed. Pressure on the inner part of the grip forces the tube freely through the distal end of the outer part of the grip so that the distal end of the tube passes down along the rod over the legs of the forceps, which are thus compelled to close. This grip dispenses with the ring, which not only interferes with the field of vision, but also renders the instruments difficult to take to pieces and to clean. It also completely avoids the fault common to so many forceps in which the closing is effected by the end of the tube. With this grip the forceps remain *in situ* and do not, on being closed, run upward toward the operator's hand. Instability of the forceps through torsion of the rod is overcome by the free end of the tube being oval in cross-section to correspond with the spreading out of the legs of the forceps.

"In all the above instruments the tube throughout the greater part of its length is only half complete, being semicircular in cross-section. At intervals narrow rings of wall are left which safely confine the rod within the tube. That the cleaning of the tube is thus much simplified is obvious."

end; 2d, an inner part made up of the inner part of the handle or grip, screwed into which is the rod carrying on its free end the ring for encircling the legs of the forceps; and 3d, the spring. He has simply applied these general principles to a special need, and the workings of his instrument will at once become apparent on inspection of the figure.

The general principles of the "lower operation" are the same as those already enumerated. Theoretically, this lower operation is less liable to be followed by infection than the upper one, as the instruments do not have to traverse the mouth or pharynx. On the other hand, there must be taken into account the added risk of a tracheotomy. The following general rule may be given as to the choice between the upper and the lower method:—The lower method, preceded by tracheotomy, is the one generally to be preferred in all cases of emergency, such as those in which there are extreme dyspnœa and a tendency to collapse, or in which it is probable that the search for the foreign body will consume a great deal of time.

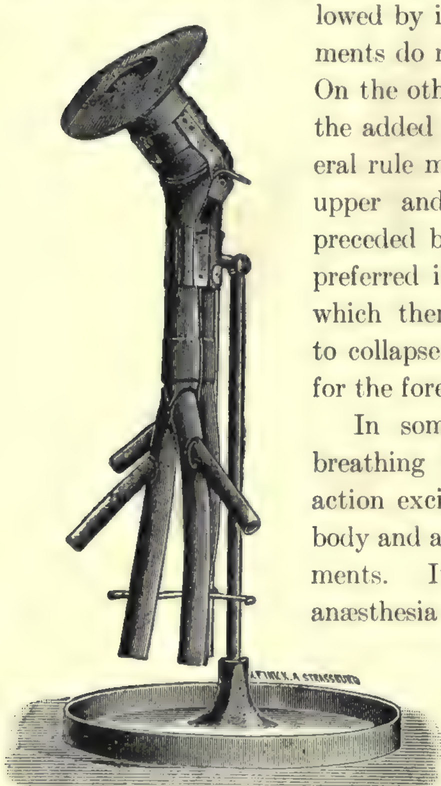

FIG. 438.—The Killian Phantom, for Use in Learning how to Employ the Bronchoscope Successfully.

In some instances is has happened that the breathing has suddenly ceased through the reflex action excited in part by the presence of the foreign body and also in part by the introduction of instruments. It is, therefore, important that general anæsthesia should be employed with great caution in these cases, and it has been proposed to protect the respiratory centres by a hypodermic injection of atropine. On the other hand, it must be added that this very procedure is not regarded as entirely safe by some clinicians who have had experience in removing foreign bodies through the tubes, as sudden deaths have followed what seemed to be the successful employment of instruments. Special attention is called to the necessity of promptly removing such bodies as peas, beans, grains of corn, etc., which, by their imbibition of moisture from the bronchial mucous membrane, increase in size, rendering extraction more difficult and the danger of local inflammation greater.

It is obvious that in all the foregoing manipulations care, gentleness, and infinite patience are required. If practice on the Killian phantom (Fig. 438) is possible it should certainly be done before one makes an examination upon the living patient.

As bearing on the results of these modern procedures we may refer to the statistics collected by Coolidge, who found records of 49 cases. The foreign body was located on the right side in 29, on the left in 11, not stated in 5, and in the trachea in 4. The upper operation was done in 20, and the lower in 29. All but 4 were successful, and of these, 3 * were in an extreme condition at the time of intervention.

In the *Centralblatt f. Laryngologie* (Jan.-Oct., 1906) we have found records of 16 cases. The foreign body was on the right side in 8, on the left side in 2, not stated in 6. The upper operation was done in 2, the lower in 9, not stated in 5. Of the 16 cases 12 were successful. In 2 the employment of the tube did not reveal the spot where the foreign body was located, but during the examination it was dislodged and expelled by coughing. Death followed in 2 cases. In 1 the foreign body was coughed out and sepsis followed. Autopsy revealed an abscess of a cervical vertebra. In the other fatal case the foreign body was located and removed, but death followed from septic pneumonia.

References:—Coolidge: Transac. American Laryngolog. Assoc., 1906.—Morton: *Journal of Laryngology,* vol. xxi., 1906.—Roe: Burnett's "System of Dis. of the Eye, Ear, Nose and Throat," 1893.—Killian: *Arch. f. Laryngologie,* Bd. xiii.; and *Journal of Laryngology,* vol. xvii., 1902.

* Not stated whether the upper or the lower operation was performed in these cases.

LARYNGECTOMY.

By FRANK HARTLEY, M.D., New York City.

Brauers, Watson, and Billroth deserve the credit for the introduction of laryngectomy for malignant disease of the larynx.

More certain methods of diagnosis and earlier operations have lessened the mortality, and have given promise that the future results will be still further improved. (*N. Y. Med. Journal,* 1902, Dec. 13th and 20th.) The diminution in the operative mortality from 1889 to 1900 was from 44 per cent to 8.5 per cent, or 14 per cent, according to one's interpretation of the operative statistics made previous to and during this period. During this same period the increase in the number of those who had remained free from recurrences for a longer period than three years, was from 7 per cent to 15 per cent, or 16 per cent. The increase in number of those who remained free from recurrences for periods of time varying from one to three years was from 13 per cent or 14 per cent to 33 per cent, while from 36 per cent to 38 per cent died within one year from complications or accidental causes. Indeed, from 1900 to the present time, the results have again improved. von Bruns, in 1906, in the *Deut. med. Wochenschrift,* XXXII., No. 38, published a series of 10 cases of thyrotomy, and quotes 7 recoveries of from two to fifteen years' duration without a death. He refers to a series of 188 total extirpations of the larynx, from 1873 to 1894, with a mortality of 44 per cent, recurrences 32 per cent, and 12 per cent cured for a year or more; while in a report of 114 cases of thyrotomy performed since 1890 he gives the following results:—Deaths, 9 per cent; recurrences, 22 per cent; cures for at least one year, 48 per cent. Glueck, in a report published in the *Brit. Med. Journal,* Oct. 31st, 1903, gives a series of 22 complete laryngectomies, with a mortality of 4.54 per cent, and one of 27 hemilaryngectomies with a mortality of 3.7 per cent. Wolkowitz, in the *Deut. Zeit. f. Chir.,* Bd. XC., p. 42, makes the following report:—In two cases of thyrotomy and excision, both patients recovered immediately (100 per cent); in one case a recurrence took place at the end of one year (50 per cent); in one case death occurred from an accidental cause at the end of nine months (50 per cent). In 7 partial laryngectomies, all the patients made immediate recoveries (100 per cent); in 57.14 per cent there were recurrences, at periods varying from three months to two and one-half years; in 28.57 per cent the patients died from complications (tuberculosis, etc.) or from accidental causes; in 14.28 per cent the ultimate history of the patients was unknown. In 15 total laryngectomies the operative mortality was 20 per cent and operative recoveries 80 per cent. Of the latter, 20 per cent remained cured for thirteen, fourteen, and eighteen years; 20 per cent were free from recurrences for seven, sixteen, and twenty-four months; 26.67 per cent died several months after operation from accidental causes or from complications (tuberculosis, etc.); 13.33 per cent died of early recurrence. The statistics of Semon show brilliant results: 20 thyrotomies, with 1 death, 2 relapses, and 17 cures that lasted for periods varying from one to thirteen years—in other words, 85 per cent of fairly durable cures. "The cured," says Semon, "have excellent health and are able to dispense with the cannula; 6 of them speak with a remarkably good tone of voice, while the others have rather weak voices, but are generally able, nevertheless, to make themselves understood."

This steady improvement in the results may rightly be attributed to the measures which have been taken to prevent aspiration pneumonia and infection in the cellular tissue enclosing the trachea. These measures are the following:—

(1) The employment of a general anæsthetic is now less often advocated; local anæsthesia being preferred by nearly all surgeons.

Cocaine, formerly used by Billroth and Semon, was extensively used by Kocher and Kroenlein, for the purpose of preventing cough, diminishing pain, and stopping hemorrhage.

General anæsthesia (especially that produced by ether) is attended by reflex irritability of the trachea and bronchi (as shown by cough and increased secretion), whereas local anæsthesia is attended by no such effects. Cocaine, furthermore, aids in defining more clearly the boundary line which separates the new growth from the healthy mucous membrane; and by the use of this drug the inhibition of the heart and respiration, which may be produced by way of the superior laryngeal nerve, is avoided.

(2) The posture of the patient during the operation is a matter to which great importance is now attached.

The posture adopted by most surgeons is that advocated by Maas, in 1874, and now used under the name of the Rose-Trendelenburg method. By means of this posture the tendency of the secretion and of the blood, during the operation, is to flow away from the trachea, and thus to diminish the danger of an aspiration pneumonia.

(3) The division of the trachea between the first and third rings and the suture of the lower segment to the skin, immediately preceding the extirpation of the larynx, have, in the hands of Glueck, who first adopted the plan, in 1881, reduced the mortality of total laryngectomy to a point as low as 4.54 per cent.

(4) The danger of infection of the peritracheal connective tissue has been greatly diminished by shutting off the cavity of the mouth and pharynx from the wound and incidentally from the lumen of the trachea. This work has been advanced largely by Bardenheuer, Rotter, Sacchi, and Foederle.

The majority of cases of laryngeal malignant growth seen by the surgeon are beyond help. Those cases which are really relievable are usually found after an early exploratory thyrotomy. It is of great practical importance to bear this fact in mind, and to proceed to a partial or complet laryngectomy immediately after the thyrotomy, if the malignant nature of the growth is confirmed by the exploration.

There are three different methods of removing a malignant new-growth of the larynx, namely: (*a*) Thyrotomy, with or without partial removal of the contents of the larynx; (*b*) total laryngectomy; (*c*) hemilaryngectomy.

Thyrotomy and Simple Extirpation of the New Growth.—The technique of this method is based mainly upon the original work of Czerny, but has been considerably elaborated by subsequent operators. The different steps of the operation, as now performed, are as follows:—(1) The patient should be placed in the Rose-Trendelenburg posture. (2) Either local or general anæsthesia may be employed, or, if such a course is preferred, the two methods may be combined. Cocaine answers well for local anæsthetic purposes, and chloroform is to be preferred as a general anæsthetic. When the two methods are combined, either chloroform or ether may be employed as the general anæsthetic agent. The writer's preference in this class of cases is for general anæsthesia secured by means of chloroform. Ether is used only in cases of heart impairment. (3) A median incision is made through the skin and subcutaneous tissue from the hyoid bone to the first or third ring of the trachea. The anterior jugular veins are recognized, and ligated if necessary. (4) The incision is prolonged between the sterno-hyoid and sterno-thyroid muscles and the thyroid cartilage, and the thyro-hyoid and crico-thyroid membranes are clearly defined. (5) The crico-thyroid membrane is punctured and the thyroid cartilage is divided in the median line and between the vocal cords by scissors inserted in the puncture or by a knife cutting from without inward, after which the thyro-hyoid membrane is incised. The two halves of the divided thyroid cartilage are pulled apart with retractors, and the interior of the laryngeal cavity is exposed. (6) Sutures are passed through the cartilage and skin. (7) If local anæsthesia has been employed, a tracheal cannula is now inserted (tracheotomy) in the trachea, and, with a small amount of packing in the larynx, all hemorrhage into the trachea is avoided. If a combination of general and local anæsthesia is employed, chloroform, administered at first, is discontinued during the removal of the growth and the arrest of hemorrhage, and a local anæsthetic is employed. When the growth has been removed, the tracheal cannula is inserted into the trachea (tracheotomy), and the wound is packed. (Kroenlein.) If general anæsthesia alone is used, tracheotomy is performed, as a rule, immediately after the thyroid cartilage has been divided and the interior of the larynx investigated. (8) If only the soft parts are involved over a limited and superficial area, the growth is removed by means of the scissors, knife, or cautery, and the hemorrhage is stopped by the application of a ligature or by means of the cautery. If the cartilage is not involved, and if lymph nodes are not discovered over the thyro-hyoid and crico-thyroid membranes or at the greater horn of the hyoid bone, such superficial removal will suffice; but if the growth is more deeply seated but circumscribed, the cartilage, with the growth attached, should be removed, the external perichondrium being allowed to remain. The hemorrhage is arrested by the careful application of a ligature or by the employment of the cautery. After the growth has been removed and the hemorrhage arrested, two sutures are passed through the skin and cartilage on each side. These sutures, however, are not tied tightly at this time.

If the space for operating proves to be inadequate, the cricoid cartilage may be divided in the median line, but this course is not advocated unless the removal of the growth cannot otherwise be accomplished.

The wound, in all cases, is treated as an open one, and is packed with gauze. Butlin, Semon, and others remove the tracheal cannula as soon as the

FIG. 439.—This figure shows the incision for thyrotomy, the division of the thyro-hyoid and crico-thyroid membranes, and the division of the thyroid cartilage. On each side is seen the crico-thyroid muscle and the sterno-hyoid muscle. Within the larynx is seen, on one side a growth covering the vocal cord, and on the other the unaffected vocal cord and the sacculus laryngis. Before removing the tumor it will be necessary to perform tracheotomy below the cricoid cartilage and above the isthmus of the thyroid gland. (Original.)

operation is finished, and close the laryngeal cavity by sutures passed through the cartilage and the soft parts. It is safer, however, to tampon the cavity for two or three days until all hemorrhage is stopped. The removal of the cannula and the suturing of the laryngeal cartilage and the soft parts should be postponed until this result shall have been secured. It has not infrequently happened that after the larynx has been sutured and after the effects of the application of the cocaine or adrenalin preparation have passed off, the hemorrhage has returned and has necessitated tamponing the laryngeal cavity. The after-treatment consists in changing the outer dressing sufficiently often to keep the surface of the wound dry.

For two or three days following the operation the patient remains in bed, the foot of which should be raised. During this period rectal feeding and irrigation are practised. On the third day the patient may begin to swallow water. He will have very little difficulty in accomplishing this. At this time also the packing is changed, and, if it be thought expedient, the wound is closed by the sutures which were passed through the cartilage and skin (but not tied) at the time of the operation.

The results of this operation are as follows:—According to von Bruns there were 74 per cent of recoveries, death occurring ultimately after periods that varied from two to fifteen years; according to Wolkowitz there were 100 per cent of recoveries; and according to Semon there were 85 per cent of recoveries, with freedom from a return of the disease for periods varying from one to thirteen years. According to this last authority the mortality from the operation amounted to 5 per cent.

The conditions essential to success are: An early diagnosis, a radical removal of a circumscribed and superficial mass, and an early state of intrinsic malignant disease.

Where more than an excision of the soft parts of the larynx is required, either as a result of the extension of an intrinsic cancer or because a cancer is situated primarily in the mucous membrane covering the epiglottis, the arytenoid cartilages, the recessus pyriformis, the ary-epiglottic folds or the pharyngeal surface of the larynx (extrinsic cancer), one must proceed to either a total or a unilateral laryngectomy; and for such an operation general rather than local anæsthesia will be required. It is, I think, the prevailing opinion among surgeons that general anæsthesia is preferable as soon as the disease involves the soft parts to any great extent and requires a removal or at least a search for affected lymph nodes in the neck.

Statistics have been so much improved by attention to posture during the operation, by careful and intelligent anæsthetization, by the avoidance of the tampon-cannulæ, and by the careful inspection and removal of perilaryngeal lymph nodes that the operation of unilateral laryngectomy may be looked upon as an acceptable middle step between the thyrotomy and partial excision of the interior of the larynx, on the one hand, and the total laryngectomy and removal of the perilaryngeal lymph nodes, on the other. Although the mortality in this class of cases is higher than one desires, and the permanent cures relatively few, both this operation and that of total laryngectomy are perfectly justifiable. If successful results, however, are to be attained it is necessary that a diagnosis should be made at quite an early stage of the disease and that an attempt at complete removal of the growth should follow promptly. A further requisite is that only the prelaryngeal and the lateral laryngeal lymph nodes shall be involved, the peritracheal and the deep cervical lymph nodes being quite free from disease. (*Vide Deutsche Zeitschrift für Chirurgie,* No. LV.; article relates to lymphatics of the larynx.) In no instance in which the deep cervical or the peritracheal lymph nodes are involved have I seen a permanent recovery. In all of them an early recurrence has taken place.

Total Laryngectomy.—The operation of total laryngectomy is usually performed in cases of extrinsic cancer without œsophageal or pharyngeal involvement, or in cases of primary intrinsic cancer with secondary extrinsic involvement. In such cases the total laryngectomy is combined with a complete removal of the prelaryngeal and lateral laryngeal lymph nodes. In these cases a previous thyrotomy and tracheotomy may have been performed; but it makes no difference so long as the wounds are healed, for the steps required in the opera-

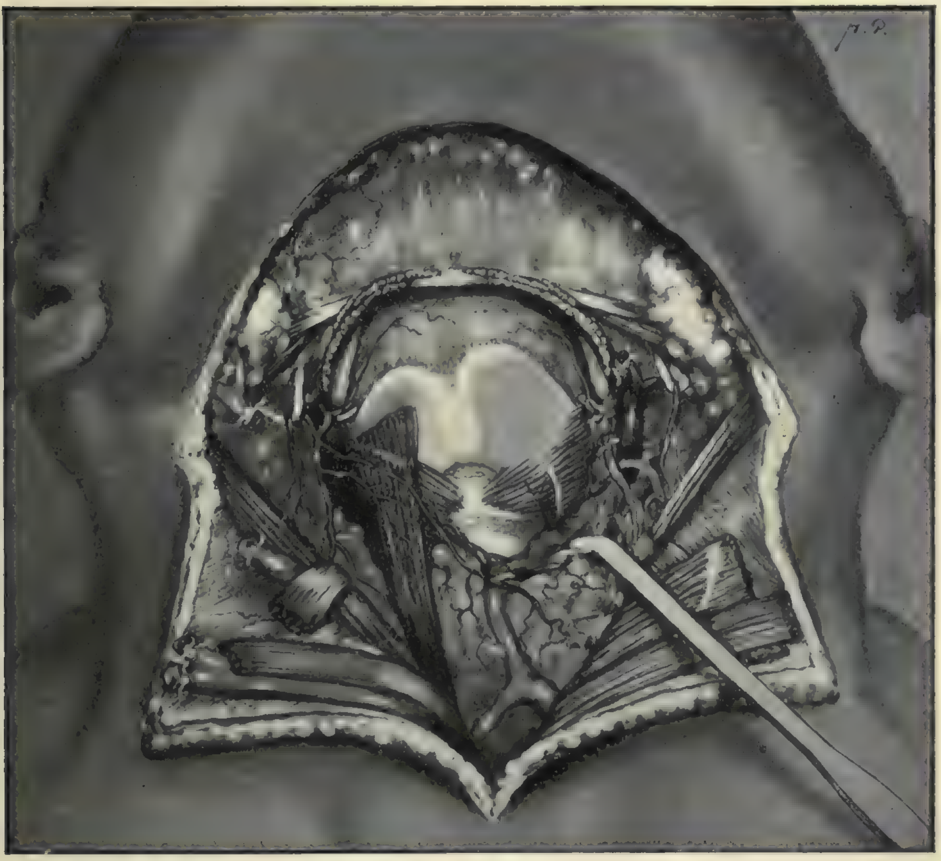

Fig. 440.—This figure shows the incisions exposing the larynx (steps vi. and vii.). On the right side (left, in the picture) the anterior and oblique jugular veins are ligated, and the superior thyroid artery is ligated just to the inner side of the internal jugular vein; on the left side (right, in the picture) it is not ligated. On the left side (right, in the picture) the thyro-hyoid and sterno-thyroid muscles, which have not been separated from one another at their attachment to the oblique line, are pulled away, exposing to view the thyroid branch of the superior thyroid artery, which communicates with the same branch of the opposite side along the upper border of the thyroid gland. On the right side (left, in the picture) the muscle is left and the crico-thyroid branch is seen on it. The superior laryngeal nerve is seen piercing the thyro-hyoid membrane. The remaining structures are easily made out as they are clearly defined. (Original.)

tion, when made under these circumstances, are the same as when a thyrotomy and a tracheotomy have not been previously performed. The method which the writer prefers is the following:—(I) The patient should be placed upon the operating-table, upon his back, but with the head slightly inclined (Rose-Trendelenburg posture). (II) The administration of a general anæsthetic (preferably chloroform) should be preceded by a hypodermic injection of the sulphate of atropia (gr. $\frac{1}{100}$). (III) An incision is next made, through the skin and subcutaneous tissue, from the hyoid bone to the jugulum sterni. The raphe between the sterno-hyoid muscles, the thyroid cartilages, the crico-thyroid membrane, and the isthmus of the thyroid gland are in turn exposed. (IV) A transverse incision passing 1 cm. below the hyoid bone, from the sterno-mastoid muscle of one side to that of the other, is now added to the vertical one. This incision is deepened

FIG. 441.—In the lower angle of the wound is seen the trachea sutured to the skin. Just above it may be seen the anterior œsophageal wall with the posterior crico-arytenoidei and the arytenoidei muscles attached. On each side, above this spot, are seen the divided pharyngeal constrictors, the palato-pharyngeus and the stylo-pharyngeus muscles, and (in the opening) the pharyngeal mucous membrane. The ligated superior thyroid artery, the divided superior laryngeal nerve, the carotid artery, and the internal jugular vein may also be seen on both sides of the wound. Near the top of the picture, in the median line, may be seen the larynx turned upon itself. (Original.)

until the subcutaneous tissue and the platysma are divided and the omo-hyoid and sterno-hyoid muscles are exposed. (V) The anterior and oblique jugular veins are ligated. The sterno-hyoid, the thyro-hyoid and, where necessary, the omo-hyoid muscles are divided near the hyoid bone. (VI) The flaps thus formed, consisting of the skin, platysma, sterno-hyoid and omo-hyoid muscles, are retracted laterally, exposing the carotid triangles of each side. (VII) The superior thyroid artery and vein upon both sides are ligated with double ligatures, near the carotid artery or, at least, before the laryngeal branch is given off. The superior laryngeal nerve may be divided at this time if one considers that the occurrence of shock is thereby rendered less likely. (VIII) In appropriate cases—*i.e.*, where the cartilage is not involved—the sterno-thyroid and the thyro-hyoid muscles may be separated from the oblique line of the thyroid cartilage and retracted with the original flaps. The region bounded above by the

Fig. 442.—In the median line above is seen the mucous membrane of the œsophago-pharynx sutured with two rows of sutures, only one of which shows in the picture. Below, in the median line, are seen the two sterno-thyroid muscles sutured and covering the œsophagus. On either side is seen the thyroid gland and the sterno-hyoid and omo-hyoid muscles. Above are seen the attachments of the omo-hyoid and sterno-hyoid muscles and of the thyro-hyoid muscle. These muscles are later to be sutured together, placed over the pharynx, and again sutured in the median line. No opening is left in the œsophago-oro-pharynx. All feeding is done by catheter passed through the nose and left permanently in place. At the lowest angle of the wound is seen the tracheal opening sutured to the skin. (Original.)

hyoid bone, below by the lower margin of the thyroid gland, and laterally by the internal jugular vein and carotid arteries, then lies completely exposed to view.

If the growth occupies the larynx above the vocal cords, we expect to find lymph nodes upon the thyro-hyoid muscle, near the lesser cornu of the hyoid bone or over the carotid artery at its bifurcation, in the triangle marked out by the sterno-mastoid and the omo-hyoid muscles and the posterior belly of the digastric muscle. If the growth occupies the region below the vocal cords, we must first search for nodes over the crico-thyroid membrane and muscles and over the isthmus of the thyroid gland, and then afterward raise the lateral lobes of the thyroid gland and examine the spaces which they cover, especially the area between the trachea and the œsophagus and that behind the œsophagus. This is not a difficult thing to do, as the superior thyroid artery and vein of both sides have been divided. If the peritracheal or deep cervical lymph nodes are found to be enlarged, I believe that operative procedure will fail, and that it is best to content one's self with palliative measures. (IX) If these lymph nodes are not enlarged, the capsule of the thyroid gland is divided above the isthmus, and the isthmus itself is pushed down, if possible, far enough to permit the trachea, divided transversely at the crico-tracheal membrane, to be pulled forward, and sutured by several sutures to the skin at the lower angle of the incision. This attachment to the skin must be effected in such a manner that there shall be no tension upon the trachea, and in order to bring it forward,

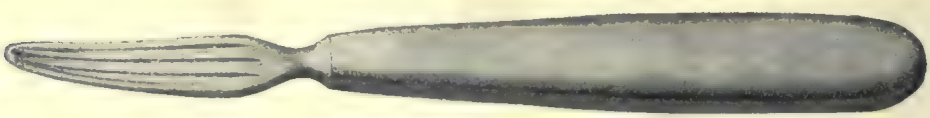

Fig. 443.—Kocher's Enucleator.

especially in short-necked individuals, it is necessary to loosen thoroughly this structure from the œsophagus and to divide the isthmus of the thyroid gland. This operation and the division of the isthmus of the thyroid gland are best accomplished, as in thyroidectomy, with the aid of the enucleator (Kropfsonde) and histotribe used by Kocher. (Figs. 443 and 444.) *

(X) At this stage the cricoid cartilage, with its lumen well tamponed, is pulled forward and is separated from the œsophagus, the inferior constrictors, and the posterior crico-arytenoid muscles. The recurrent laryngeal nerves are divided and the cavity of the pharynx is entered. The laryngeal box is now easily lifted and the inferior constrictor, the stylopharyngeus, and the palato-pharyngeus muscles are separated from the thyroid cartilage as far as the upper border. (Fig. 441.) If this has not already been done, the superior laryngeal nerves are now divided (XI) and the thyro-hyoid membrane is cut transversely below the hyoid bone, leaving the larynx attached above by the epiglottis and the ary-epiglottic folds. If the epiglottis is not involved, it may be left; if involved, it may be removed by dividing the linguo-epiglottic mucous membrane, the submucous fat, and the hyo-epiglottic ligament. The space left by the removal of the larynx is bounded below by the mucous membrane of the œsophagus and above by the divided linguo-epiglottic mucous membrane, if the epiglottis has been removed. If it has not been removed, the upper boundary will be the

* The division and suture of the trachea to the skin (Deutsche Zeitschrift für Chirurgie, 1900, Glueck) constitute a great advance in laryngectomy, and great credit should be given to Glueck, whose statistics, in 1900, gave thirty-one recoveries from operation in thirty-four cases.

divided ary-epiglottic membrane. On the sides, the cut edges of the pharyngeal wall limit the space.

(XII) The closure of the oro-œsophago-pharynx has been particularly studied by Bardenheuer, Poppert, Rotter, Sacchi, Foederle, and Glueck. (See *New York Med. Journal*, 1902, Dec. 13th and 20th.) Which of the suggestions made by these authorities is the best it is difficult to say. Could one carry out Foederle's suggestion and suture the trachea to the hyoid, and the ary-epiglottic and epiglottic mucous membrane to that of the trachea, the procedure would be ideal. In many instances, however, this cannot be accomplished, because there is too great tension upon the sutures that hold the hyoid and the trachea together. (von Keppel's case, *Langenbeck's Archives*, No. 63.)

The best results obtained by the writer have been secured by suturing the mucous membrane of the œsophago-pharynx over a small catheter that is passed through the nose down to the stomach. The mucous membrane is

Fig. 444.—Kocher's Histotribe.

sutured with two rows of fine silk, each stitch including the pharyngeal wall, but not perforating the mucous membrane. The sterno-hyoid, thyro-hyoid, sterno-thyroid, and omo-hyoid muscles are sutured together in such a manner as to cover the pharynx. Then over these muscles the skin is sutured. This has been the method used in the writer's last three complete extirpations. It has permitted early and full feeding, so necessary in older patients, and has contributed greatly to an early healing of the wound in the œsophago-pharynx. A longitudinal incision of the œsophago-pharynx is usually made because it is easier to apply the sutures in such a wound. A transverse incision may also be made, especially where the epiglottic mucous membrane and the œsophageal membrane over the arytenoid and cricoid have been saved. The tension upon the sutures in either the longitudinal or the transverse incision is the same, unless the head is bent well forward. The advantage of the transverse over the longitudinal incision is that the œsophago-pharynx can be completely shut off from the wound, while in the case of a longitudinal incision there is sometimes left, near the hyoid, a small opening which cannot be closed by suturing. In both cases, feeding by means of a catheter passed through the nose is preferred to feeding by the mouth, although the use of the catheter is not absolutely necessary when a transverse incision is made. I have never known a decubitus ulcer to result from the employment of the catheter.

In some instances a total laryngectomy is performed after a crico-thyrotomy or a tracheotomy (either the high or the low operation) has been done to overcome spasms or asphyxia, or to oxygenate the patient's blood and so to stimulate his heart action. If a crico-thyrotomy be the method employed, one should proceed as in the typical operation. If a high tracheotomy was employed, the trachea is cut transversely at the level of the former tracheotomy wound and is sutured to the margin of the skin, exactly as is done in the typical operation. Finally, if the case is one in which a low tracheotomy has been performed so recently that the wound has not fully healed, the trachea should be divided transversely above the wound of the previous tracheotomy, and two rows of sutures should be applied to the edges of this new wound in order to attach them to the skin at the lower angle of the incision. The first row of sutures should pass through the cartilage, and the second one through the submucous connective tissue after it has been set free. If the case is one in which the wound resulting from a previous low tracheotomy is already firmly healed, simply a fistulous opening into the trachea remaining, one or two rings above the tracheal fistula are enucleated and the mucous and submucous tissues are carefully sutured in such a manner as to shut off the tracheal opening from the wound. The tracheal fistula is thus made to serve as a channel for the admission of air.

After-treatment.—The after-treatment in total laryngectomy is of the greatest importance. The air of the room should be kept moist and the temperature uniform. The patient lies on his side, this position favoring the escape of the bronchial secretions and preventing stagnation in the bronchial tubes. The day after the operation the patient is allowed to sit up, in order to give full play to the lungs and to prevent pulmonary congestion. At all times, when the slightest tracheal rattling, stoppage of respiration, or cyanosis occurs, a careful mopping of the tracheal orifice and the trachea itself must be carried out with curved cotton-carriers armed with sterilized cotton. Death may occur in any of these attacks unless care is taken. The accident is only of a transitory character, and if one excites the reflexes by the use of the cotton-tipped probes these inhibitory phenomena, due to the dragging upon the laryngeal nerves, is quickly overcome. The dressings applied to the wound in the neck are the same as those applied to wounds in other parts of the body. Moist gauze, which should be frequently changed, makes a useful dressing for these cases. For the eight or ten days immediately following the operation, only liquid nourishment should be given. During the first forty-eight hours, it should be administered by way of the rectum, but subsequently it may be introduced through the catheter that has been passed through the nose into the œsophagus and stomach at the time of operation and left *in situ*. It is better, according to the writer's experience, to allow this catheter to remain permanently in position, so that feeding may be done early and that the sutured pharynx may be disturbed as little as possible. If, after the eighth or tenth day, it is found that the edges of the wound have united, feeding may be carried on by way of the mouth. As often every day as may seem necessary, means should be employed to keep the bucco-pharyngeal cavity aseptic.

Complications.—The complications which occur after the operation are: shock, secondary hemorrhage, suppuration in the wound, œdema of the margins of the tracheal opening, and broncho-pneumonia.

Certain individuals die three or four days after the operation without elevation of temperature and without any signs of broncho-pneumonia or septicæmia. The inference in such cases is that the patient has died of shock.

Suppuration in the wound and secondary hemorrhage are, fortunately, events of comparatively rare occurrence.

Œdema of the margin of the tracheal orifice may readily be overcome by the introduction of a tracheal cannula.

Broncho-pneumonia is the most frequent complication, and it is for the purpose of preventing it that the tracheal orifice is completely isolated from the rest of the wound, that the oro-pharynx is closed completely, and that so much attention is paid to securing a humid and warm atmosphere for the patient to breathe during the eight or ten days immediately following the operation.

Prognosis.—The favorable character of the prognosis of total laryngectomy, as regards both a cure and a recurrence of malignant disease, is directly proportionate to the earliness of the discovery of the disease, to its circumscribed character, and to the completeness of the operative procedures for its removal.

Results.—The results of the operation of total laryngectomy may be stated as follows:—

The mortality resulting directly from the operation is given by Glueck as 4.5 per cent, and by Wolkowitz as 20 per cent. As regards those who survived the operation (80 per cent), 25 per cent of the number died from a recurrence of the disease thirteen, fourteen, and eighteen years after the operation; 26.5 per cent died of accidental diseases; 15 per cent were free from a recurrence seven, sixteen, and twenty-four months after the operation; 13.5 per cent died of early recurrences.

During the first fifteen days after the operation death is usually due to shock or to broncho-pneumonia. After fifteen days death is usually due to a recurrence of the growth, and, in the greater number of instances, this occurs about the tenth month.

Prosthetic Apparatus.—Czerny was the first to recommend the use of an artificial larynx, but Gussenbauer was the first to make actual trial of the apparatus upon the living. Various kinds have been invented by Foulis, Mathieu, Narath, and Glueck, but in their construction they are, in the main, alike. It must be admitted that these contrivances, though well made and ingeniously constructed, present some inconveniences. The tone of voice thus produced is monotonous. The production of the noise causes the patient considerable fatigue, and with each act of deglutition there is some pain and discomfort. The writer is not in favor of prosthetic apparatus for the voice, as he believes that they have a tendency to irritate and consequently must favor recurrence. With the proper education, the function of the lost organ can be well replaced by the remarkable adaptability of that portion of the pharynx which is situated between the tongue, the epiglottis, and the œsophagus. The writer's best case (operation performed six years ago) talks well enough to be heard across the room (a distance of ten feet), and, in doing her shopping in the stores, she is easily heard and understood. She is rarely asked to repeat any questions.

(Consult Goldstein's case (Verhandlungen der Deutschen Gesellschaft für Chir., 1900, II., 652), Hartley's case (*New York Med. Journal*, 1902, Dec. 13th and 20th), and Schmidt's case (*Archiv für klinische Chir.*, 38, 132.)

Hemilaryngectomy.—The indications for hemilaryngectomy are, first, the confinement of the malignant disease to one side (either intrinsic or extrinsic), and, second, the slight degree to which the lymph nodes, on the side corresponding to the disease, are involved. The choice of this operation is of course still more strongly favored when it is found that the lymph nodes have escaped altogether.

Inasmuch as a laryngoscopic examination cannot be depended upon to furnish trustworthy information as to the unilateral location of the disease,—for the laryngoscope brings into view only those parts which are situated above the glottis,—it will be necessary, in addition, to resort to thyrotomy, in order to secure a direct view of the subglottic region. It is only in this way that one can assure himself that there are no subglottic prolongations, that the laryngeal cartilage has not been invaded, and that the malignant growth has not involved both sides. Such extensions of the disease are often only seen when the divided thyroid cartilage is widely retracted. In every case, therefore, when a hemilaryngectomy is contemplated, the operation should not be finally decided upon until an exploratory thyrotomy shall first have been performed.

The writer's method of procedure is as follows:—(I) Before general anæsthesia is induced by means of chloroform, a hypodermic injection of the sulphate of atropia (gr. $\frac{1}{100}$) is administered. (II) The patient is placed in the Rose-Trendelenburg posture. (III) An incision is made from the hyoid bone to the third or fourth ring of the trachea, in the median line of the neck. (IV) This incision divides the skin and the subcutaneous tissue. The anterior jugular veins are either avoided or ligated. The incision in the median line brings into view the raphe between the sterno-hyoid muscles, and the thyroid cartilage and the crico-thyroid membrane are laid bare. (V) Then with the scissors or knife the crico-thyroid membrane is punctured and the thyroid cartilage is divided in the median line. The two sides of the divided thyroid cartilage are pulled apart by retractors, thus making it easy to inspect every part of the cavity of the larynx. If, as a result of such inspection, it is found that the malignant growth is confined to one side of the larynx and that affected lymph nodes are discoverable only on this side of the neck, a unilateral laryngectomy is the operation which should be preferred. As a further reason for such preference may be mentioned the fact that after the parts have healed the voice returns in a more or less perfect measure. If it is found, however, that the disease is not confined to one side, but involves both sides of the larynx, removal of the entire organ should be decided upon. With this object in view (VI) a tracheotomy should be performed at as low a point as possible, usually at the third or fourth ring. This may be done by dividing the attachment of the capsule of the thyroid gland to the cricoid cartilage transversely and by pushing the isthmus downward sufficiently to expose the third and fourth rings. If this does not accomplish the object desired, the isthmus may be loosened from the trachea with Kocher's enucleator (Fig. 443) and then divided with the histotribe (Fig. 444); whichever of these procedures is used does not matter. An opening is made in the trachea, the cannula is inserted, and the administration of the anæsthetic is continued through it. In some instances it has been found necessary, on account of asphyxia present or threatened, to do a tracheotomy eight or ten days before the operation of laryngectomy. In other instances this is the method of choice, and in these cases the anæsthetic is administered from the beginning through the tube. (VII) The larynx and trachea, above the tracheotomy wound, are packed loosely with gauze. (VIII) A transverse incision, extending from the sterno-mastoid muscle of the diseased side to the median line, is made just below the hyoid bone. The sterno-hyoid, omo-hyoid, and thyro-hyoid muscles are divided in the line of the incision. In the slighter cases the thyro-hyoid and the sterno-thyroid muscles may be separated from the oblique line in one piece, but it is better to sacrifice these muscles by removing them with the larynx. When this course is adopted, the sterno-thyroid is divided at the lower level of the cricoid cartilage. (IX) The flap composed of the skin, the platysma, and the omo-hyoid and sterno-hyoid muscles, is drawn outward, exposing the carotid triangle of the neck. With further retraction one may expose the area bounded above by the hyoid bone, below by the lower margin of the thyroid gland, laterally by the internal jugular vein and the carotid artery, and medially by the healthy half of the larynx and trachea. The lymph nodes in this area are now investigated and the practicability of completely removing them is decided. If their removal seems practicable, the superior laryngeal nerve is divided and the superior thyroid artery and vein are tied close to the carotid. Then the crico-thyroid branch, the superior thyroid branch, and the superior transverse communicating branch of the same artery are also tied. The lymph nodes may now be removed. (X) The superior horn of the thyroid cartilage is next cut, and the constrictor muscles are separated from its posterior margin. (XI) The crico-thyroid muscle is divided, if the conditions are such that the cricoid cartilage can be retained, and then afterward the inferior horn of the thyroid cartilage is cut. If the cricoid cartilage cannot be retained it is divided in the median line with cutting forceps, and the ligamentum crico-tracheale and mucous membrane are incised with the thermo-cautery. After this the plica interarytænoidea and the mucous membrane of the inner surface of the cricoid cartilage are divided with the thermo-cautery. The movable half of the larynx is turned toward the opposite side to expose its posterior surface, in order that one may determine whether it may not be possible to save the mucous membrane which covers it. If it is found that this cannot be done with safety, the mucous membrane is removed with the half of the larynx. If the half of the cricoid cartilage is removed, the separation is made between the first tracheal ring and the cricoid cartilage after the cartilage has been divided anteriorly and posteriorly. If the cricoid is saved, the separation is made at the crico-arytenoid articulation and at the upper margin of the cricoid cartilage. (XII) The mucous membrane of the laryngeal wall is sutured to the mucous membrane of the lateral wall of the pharynx when feasible. In this manner the pharynx is in a measure separated from the laryngeal cavity. In some instances the writer has been able to suture the lateral wall of the pharynx anteriorly to the aryteno-epiglottidean folds and to the mucous membrane lining the half of the thyroid cartilage. In addition to the suturing just described, the mucous membrane of the internal and posterior aspects of the cricoid cartilage is sutured over the cricoid. In this manner all raw surfaces are excluded from the pharynx. Over the parts thus sutured together the muscles (omo-hyoid and sterno-hyoid)

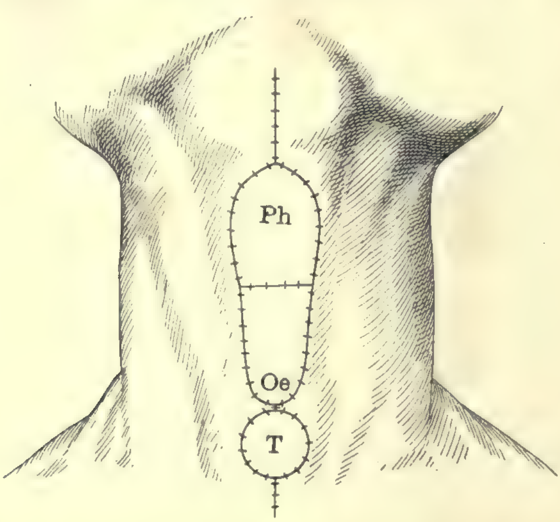

Fig. 445.—Diagram Showing the Appearance of the Wound After Suture of the Œsophagus and Pharynx posteriorly and of the Pharynx and Œsophagus to the Skin Laterally. This is the first step toward the plastic closure.

T, the trachea; *Ph*, the pharynx; *Oe*, the œsophagus. (Modified from Navratel, *loc. cit.*)

are united, a small gauze drain being placed beneath these muscles up to the point where they join the mucous membrane. In the cases in which the last-named steps were carried out, the patients were able to swallow without difficulty. Where the raw surface cannot be excluded from the laryngeal cavity, a tampon is applied after the lateral pharyngeal mucous membrane and that of the posterior surface of the cricoid cartilage have been sutured together. (XIII) Over the tampon the divided muscles are sutured, and, last of all, the horizontal and vertical incisions are closed. (XIV) An aseptic dressing covers the outside of the wound.

After-treatment.—Rectal feeding and irrigation are necessary if a catheter has not been passed through the nose or through the mouth and left permanently in place. At the end of three days the patient is permitted to swallow water. With the foot of the bed raised, the patient swallows "up hill," as it were. This is a much better plan than when the patient occupies the reverse position. If he fails in this attempt the catheter should be used for some days. Where

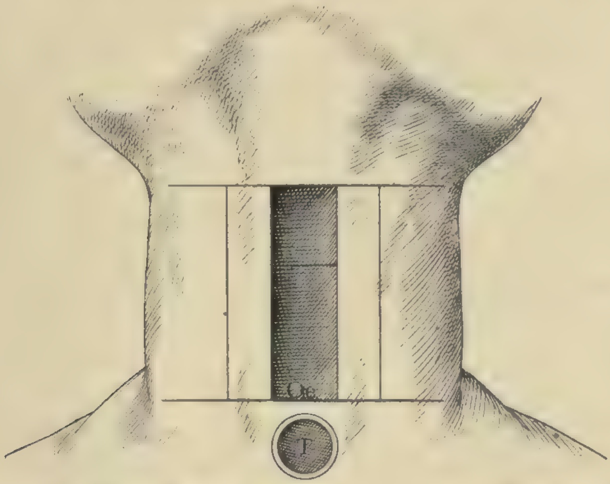

Fig. 446.—Diagram showing the lines of the incisions required for the plastic closure of the œsophago-pharynx or œsophagus after completion of the first step. (See Fig. 445.)

The two narrow vertical flaps, one on each side of the œsophageal opening, are so far freed from their attachments that their outer halves may be folded over and united by sutures in the median line, thus furnishing a new anterior wall (skin-lined) for the œsophagus. The two larger flaps are loosened in a similar manner and then stretched until their free edges meet each other in the median line. United by sutures in this position, they form a perfect covering for the entire front part of the neck, as shown in Fig. 447. *T*, The opening into the trachea; *Oe*, the œsophagus. (Navratel, *loc. cit.*)

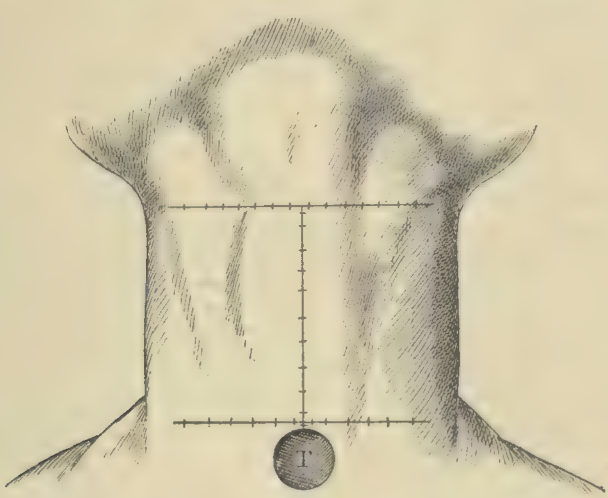

Fig. 447.—Plastic Closure Completed. (See Fig. 446.) *T*, the Trachea. (Navratel, *loc. cit.*)

feeding is to be carried on for some time through a catheter placed permanently in the nose, the nourishing fluid should be introduced for the first time on the day after the operation, and the feeding should be repeated daily afterward. Rectal irrigation should also be performed daily. The permanent catheter is usually removed on or about the eighth day; the tracheal cannula a few days later (from the tenth to the fourteenth). The tampon is removed on the second or third day after the operation, and a fresh one inserted in its place. With each new tampon the quantity of gauze used should be less and less.

RESULTS OF THE OPERATION.—After healing has taken place, the neck will present a rather deep excavation covered with skin. Opposite the vocal cord there will be formed, in many instances, a membrane, which serves as an artificial glottis and sometimes produces a very good voice. In a few instances stenosis follows, especially where the wound healed with some infection, or where the dissection made in removing one-half of the larynx was not skilfully done. In the majority of cases a clear and fairly loud voice is preserved after the parts have entirely healed. Notwithstanding the fact that the operation itself is less extensive than that of total extirpation of the larynx, the statistical results are almost as bad as they are in that operation. Doubtless the very free communication which exists between the outside air and the trachea, favoring as it does the development of broncho-pneumonia, explains in large degree why the results of the operation are so unfavorable.

The mortality following the operation, in a series of twenty-seven cases, is given by Glueck as 3.7 per cent, while in seven cases reported by Wolkowitz the mortality was zero. Of these seven cases, however, four had a recurrence in

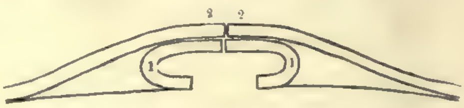

FIG. 448.—This diagram shows, in a horizontal section, how the flaps obtained from the two sets of parallel vertical incisions are to be managed in order to furnish coverings for the wound as a whole. First, the narrower flaps (1, 1) are bent over in such a manner as to bring their external borders together in the median line, thus furnishing a new anterior wall, internally covered with epidermis; and then, after these borders have been sutured together, the larger flaps (2, 2) are put on the stretch and their inner borders are sutured together in the median line, over the smaller flaps, in the manner shown in Figs. 449–452.

from three months to two and one-half years, two died from complications (tuberculosis, etc.) or from accidental causes, while in the remaining case the ultimate result was not ascertained.

INVOLVEMENT OF THE ADJACENT ŒSOPHAGUS.—It becomes necessary sometimes, in removing the larynx for malignant disease, to cut away portions of the adjacent œsophageal wall. In attempting such a laryngo-œsophagectomy, it is well to bear in mind the following facts:—

I. No primary circular suture of both ends of the exsected œsophagus has succeeded.

II. In excisions of parts of the œsophagus, most operators have, after fixing the ends to the surrounding tissues, attempted to bridge over the defect by granulation tissue. The results are unfavorable. Either a stricture or a fistula follows in every case.

III. Large portions of the œsophagus can be removed and be replaced by skin flaps without hindering in any way the descent of solids or fluids. (von

Hacker [*Centralblatt für Chir.*, 1891, p. 121], Paulsen [*Centralblatt für Chir.*, 1891, p. 15], Hochenegg [*Wiener klinische Wochenschrift*, 1892, No. 8, p. 123], Narath [*Archiv für klinische Chir.*, Bd. LV., p. 838, 1897].)

IV. Smaller defects in the œsophagus have been closed successfully by transplanting the thyroid gland (after ligating its vessels so as to mobilize it) over the sutured or unsutured defect. (Navratel: *Deutsche Zeitschrift für Chir.*, Bd. LXXXIII., p. 490.)

V. A plastic operation upon the œsophagus is easier to perform if the larynx has been removed than if it is present.

The only cases which call for consideration are those in which the larynx has been removed together with a portion of the œsophagus. If small portions of the œsophagus have been removed, the gaps can first be closed by suture and

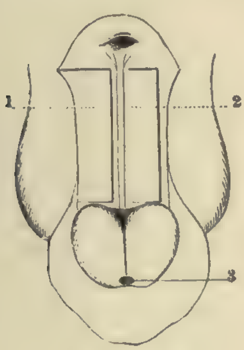

FIG. 449.

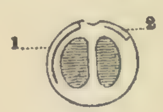

FIG. 450.

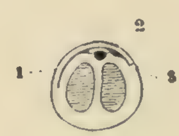

FIG. 451.

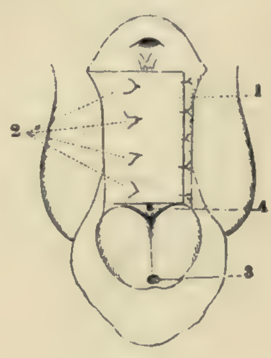

FIG. 452.

FIGS. 449–452.—Diagrams Illustrating the Principles upon which the Szymanowski Operation for the Cure of Hypospadias is Based. These same principles may be utilized in operations for closing the external wound after a laryngo-œsophagectomy. (From Szymanowski's "Handbuch der operativen Chirurgie," Braunschweig, 1870.)

FIG. 449.—1 and 2 are two elongated rectangular flaps of skin that are applied, one from the right side and the other from the left, over the groove in the penis, for the purpose of converting this groove into a tube. Flap 1, before being put upon the stretch, does not quite reach the groove. It should be about twice as broad as flap 2, which, being doubled over far enough to carry its free edge well beyond the groove, presents to the latter a surface of skin. After flap 2 has thus been doubled over, flap 1 is stretched over it—raw surface being apposed to raw surface—until its free edge reaches the edge of the wound made in preparing the latter flap. 3 represents the orifice of the covering of the glans.

FIG. 450.—Transverse vertical section of the penis, showing the relations of flaps 1 and 2 to each other and to the urethral groove. These flaps lie undisturbed in their natural positions.

In Fig. 451 flaps 1 and 2 are shown in the positions which they occupy after they have been stretched and folded in the manner described in Fig. 449.

FIG. 452.—Superficial view of the penis after the two flaps have been fixed in their proper places by the aid of sutures. 1, Flap 1 of the preceding figures. It has been drawn over and completely conceals flap 2; 2, sutures which are passed through the free margin of flap 2 to keep it in place; 3, orifice of the newly formed covering for the glans; 4, transverse cleft which remains between the newly formed penis and glans coverings. At the bottom of the cleft may still be seen a small uncovered area of the urethral groove.

then covered by and sutured to the transposed thyroid gland. In order to carry out this last step it will be necessary, owing to the immobility of the thyroid, to ligate its chief blood-vessels. After the organ has been displaced, the sutured œsophagus is fixed to the under surface of the thyroid gland by several sutures. (See Navratel, *l. c.*) If a larger portion of the œsophagus is removed, including the posterior wall or a part of it, loosen the organ from the underlying tissue, fix the ends by suture to the prævertebral muscles or fascia, and then suture the œsophageal ends, using two rows of suture—one, a submucous suture, to approximate the edges of the mucous membrane, the other to relieve tension. Silk is preferred as a suture material. The posterior wall having thus been made continuous (Fig. 445), the lateral pharyngo-œsophageal walls are sutured to the skin upon each side of the neck.

After this last step has been completed, the wound is packed with iodoform gauze which should be changed as frequently as is necessary to keep the wound dry and to make it possible to nourish the patient by the stomach tube. With the healing of these sutured areas there is formed a gutter which is composed of mucous membrane posteriorly and of skin upon the sides leading from the pharynx to the œsophagus. This gutter, at the lower end of which is seen the tracheal opening, is now to be closed. This is accomplished by making two lateral skin flaps with their hinges along the muco-cutaneous suture lines. (Fig. 446.) These flaps, after separation from the subcutaneous tissues, are folded over and sutured to one another in the median line. Then over these inverted skin flaps the edges of the skin on the side of the neck are sutured together in the median line. (Fig. 447.) A cross-section of the flaps in place is seen in Fig. 448. Szymanowsky's operation for closing an epispadias may be used instead of the above method. A full description of this operation may be found in any text-book on general surgery or in Szymanowsky's Operations. (See Figs. 449-452.)

If it is not practicable to suture together the edges of the opening left in the œsophageal wall, two quadrangular skin flaps, taken from the sides of the neck and equal in width to the defect in the œsophagus, are displaced and united, the one to the other, in the median line. Above and below, these flaps are sutured to the cut ends of the œsophagus. At a later period this gutter is converted into a canal by some plastic procedure like those already outlined above.

Since the writer published his article on this subject in 1902, he has performed three partial and four total laryngectomies for malignant disease. In the cases upon which the partial operation was performed there were no deaths and no recurrences. In those upon which the total operation was performed there was no mortality dependent directly upon the operation; there were two recoveries without a recurrence in over two years; and in two instances there were recurrences—in one at the end of three months, and in the other at the end of one year. In one case the writer performed a laryngo-œsophagectomy, with a fatal result due to sepsis.

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