PUBLIC HEALTH LABORATORY WORK AND FOOD INSPECTION

ANDREWS

HAND-BOOK

OF

PUBLIC HEALTH LABORATORY WORK

AND

FOOD INSPECTION.

BY

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PREFACE.

The lectures delivered by me to the Surgeons under Instruction at the R. N. Hospital, Haslar, have been collected into three parts which are now bound in one volume.

Part I. treats of the main points to be observed in the inspection of Fish, Flesh, and Fowl intended for human food.

Part II. includes the chief features in the examination of Water, Air, Milk, various Foodstuffs, Wines, etc.

Part III. embraces the main facts concerned with the subject of Meteorology and the influence of the various atmospheric phenomena on health and disease.

The study of Climatology has received much more notice of late years than it formerly did, chiefly owing to the increased amount of attention which is now paid to the study of the diseases met with in warm climates, for the existence of many of which, certain climatic conditions are chiefly responsible. Climatology is a study for which many opportunities are afforded by those following the sea as officers (medical or otherwise) in the Royal Navy, and a knowledge of Meteorology is essential to those who study the various climates they experience.

The want of a book comprising the above subject has been felt by numerous Naval Medical Officers, and it is hoped that this work, which has been written and compiled after some years experience in Public Health Laboratory Work, may prove of service not only to them, but also to candidates for the Diploma in Public Health of the various examining boards.

I have to express my thanks to Sir W. H. Flower, K.C.B., F.R.S., late Director of the British Museum (Natural History), and to his assistant, Mr. G. A. Boulenger, F.R.S., who have kindly assisted me in obtaining some of the drawings which appear in the portion devoted to Fish Inspection, most of which are from specimens in the Fish Gallery of the British Museum (Natural History), South Kensington, and have appeared in the "Guide to the Galleries of Reptiles and Fishes" (Fourth Edition, 1898); also to Mr. William Marriott, F.M.S., for permission to copy certain figures showing various arrangements of isobars, which appeared as illustrations in "Popular Weather Prognostics," by the late Hon. Ralph Abercromby, F.M.S., and William Marriott, F.M.S. I am indebted to Messrs. Baird and Tatlock, of Hatton Garden, for the use of electrotypes for the illustration of various chemical apparatus, and to Mr. Cassella, of Holborn Bars, for the illustrations of Meteorological instruments; and lastly, my best thanks are due to Fleet-Surgeon T. D. Gimlette, R.N., for the great assistance he has given me in helping to revise the proofs

O. W. ANDREWS.

March, 1901.

ERRATA.

On Page 13, 14 lines from the bottom of the page, insert the word "an" after the word calves.

On Page 17, six lines from the bottom, there should be a "comma" after the word pressure.

On Page 27, 24 lines from the top, for "cavaties" read "cavities."

On Page 29, five lines from the bottom, insert the word "the" after cysticerci.

On Page 41, line 19, for morphiological read "morphological."

On Page 114, line six, omit word "straight."

On Page 114, line 16, insert word "sizes" after word supports.

On Page 119, 17 lines from bottom, for the sign + substitute the word "and."

On Page 126, line 26, for the sign × substitute the word "and."

On Page 127, line 16, 20 97 should be "20 76."

On Page 127, 15 lines from bottom, omit word "and."

On Page 129, line 13, for "and" read "is."

On Page 129, line 18, for "can" read "should."

On Page 140, line 14, "1867" should be "1897."

On Page 140, line 16, for "who" read "he."

On Page 140, line 29, for "squeous" read "aqueous."

On Page 140, line 31, for "fltted" read "fitted."

On Page 140, two lines from bottom, for "drawing" read "driving."

On Page 140, bottom line, 26 should be "0·26," and for the words "All the fat in 28 cc ∴ =" read "The amount of fat in 28 cc of the etherial extract can be found by rule of three, thus"

On Page 150, line six, for "was" read "were."

On Page 167, line 19, for "mixen" read "mixed."

On Page 184, twelve lines from bottom, insert the word "or" between the two formulæ for Tartaric Acid.

On Page 210, Index, opposite Normal solutions the page should be "121."

On Page 210, Index, opposite Pellagra and maize, the page should be "168."

On Page 246, ten lines from the bottom for "inside" read "and."

On Page 279, eleven lines from the bottom, for "of" read "over," and insert the word "that" after than, and in the next line there should be a "comma" after the word abundant.

PART I.

FOOD INSPECTION.

CHAPTER I.—MEAT.

The animals supplying meat for the Royal Navy are the ox, sheep, and pig. The two first named animals are met with in two forms, viz., fresh and preserved beef and mutton, the latter only as salt pork.

It is not often possible to inspect the animals prior to slaughter, but when this is possible, it should be done. In the French Navy, bullocks are constantly taken to sea for the use of the whole ship's company, in our navy, sheep and poultry are frequently taken for the use of officers, but when taken by officers' messes they are obtained by private purchase.

In inspecting live animals the following points should be looked to :—

(*1*) Animals should be well nourished, emaciation should always arouse suspicion of disease, in any case it implies meat of inferior quality and diminished nutritive value.

(*2*) Gait should be observed, inability to rise or walk with ease implies exhaustion by disease or injury. A lame animal is generally, if not always, unsuitable for food.

(*3*) Appearance of the eyes should be noted, they are bright and clear in health, dulness implies disease.

(*4*) Mouth and nostrils in health are moist and free from discharge.

(*5*) Tongue should not hang from the mouth.

(*6*) Breathing should be tranquil, *i.e.*, unattended with noise or difficulty.

(*7*) Breath should be inoffensive.

(*8*) Dejecta should be healthy.

(*9*) The coat should be natural, free from scabs and boils; in sickness it is usually rough and staring.

(*10*) No shivering or evidence of pain should be present.

Condition.

The flesh should be firm over the *handling points,* these being:—the *aitches* or bones by the side of the tail; the *rib;* the *flank;* the *cod,* or, in the case of the cow, the *udder;* the *brisket;* the *loin;* the *rump fat;* and appearance of the back.

The rib should be well covered with firm flesh. The flank should be full and appear to sink into the hand when grasped (the flank is the lower part of the abdomen near the stifle joint, where cellular tissue is abundant). The cod in the ox, or udder in the cow, should be firm and compact. The brisket, or parts between the fore-legs, should be firm and flat (not rounded or pointed as in the horse). The loin should be well covered in a properly nourished beast. The rump-fat, on each side of the tail, should be well developed and firm. On looking at an ox, the line of the back from the root of the tail to the shoulder, should be almost horizontal.

The weight should not be less than 620 lbs. in the case of an ox, or about 560 lbs. for a heifer. Butchers determine the weight of a live animal by the following method:—

Measure first the girth close behind the shoulder (and call this G), next the length from the fore part of the shoulder-blade along the back to the bone at the tail, which is in a vertical line with the buttock (call this L). In both cases the measurements to be in feet and fractions of a foot. Weight in stones (call this W), is determined as follows:

$$(G^2 \times 5L) \div 21 = W$$

Example. Girth of an ox is found to be 6 feet, and length $5\frac{1}{4}$ feet, then

$$(36 \times 26{\cdot}25) \div 21 = 945 \div 21 = 45$$

= 45 stones or 630 lbs.

Prime beef should be from oxen not older than five or six years, the best is usually from oxen three or four years of age. To tell a beast's age by the teeth:

At the end of two years it has two permanent teeth.
At the age of three years four permanent teeth.
,, four ,, six ,, ,,
,, five ,, eight ,, ,,

These permanent teeth are larger, more square in shape, duller in colour, and the crown thicker. There are not the same inducements to offer old sheep for sale, as there are in the case of old cows. If it is necessary to determine the age of a sheep, the appearance and number of the permanent teeth should be noted. At the age of six years the teeth are at their full size after that they become worn down.

As a rule in England, old beef is cow beef. A cow will go on calving till she is 18 or 20 years of age, the flesh of old cows that have had many calves is of poor value.

	years	months			
In sheep at	1	4	there are	two	permanent incisors.
,,	2	0	,,	four	,,
,,	2	9	,,	six	,,
,,	3	6	,,	eight	,,

Mutton should be from sheep not exceeding five years of age.

Slaughter.

This is usually conducted by first securing the animal by passing a rope round the horns and thence through a ring bolt, the head is then brought down low for the convenience of the man wielding the pole-axe, which breaks through the skull and fells the beast. They are next pithed by means of a cane introduced through the wound in the forehead into the spinal canal, where the cord is broken up, and death immediately occurs. The throat is then cut, and the blood caused to flow freely through the body, by a process of kneading. By skilful butchers this process is a humane one, but I have seen the operation performed by the unskilled, and the process in that case quite the reverse. In some establishments, where none but the most skilful butchers are employed, animals are killed without being secured in the manner described above. Two blows suffice, the first delivered on the "poll," between the horns, fells the animal, and the second is directed against the forehead, in order to make an opening for the introduction of the pithing cane. Should the animal show signs of being refractory, the rope is brought into use.

Greener's humane cattle killer (*Figs 1 & 2*) leaves nothing to be desired, it consists of a short rifled barrel, chambered at the breech end to receive a small cartridge, with a bullet steel-pointed in order to ensure penetration, the muzzle terminates in a trumpet shaped extremity, which is said to deaden the sound of the discharge, and at the same time directs the bullet through the brain into the spinal cord. At the breech is a projecting pin or nipple, which fires the cartridge when struck with a small mallet. The instrument should be placed well up on the animal's forehead, slanting upwards, so that the barrel is in line with the spinal canal, as in the woodcut, with the small knob on the bell-shaped end uppermost. Animals bleed well when killed by Greener's method. In New Caledonia, I have seen slaughtering carried out by a man armed with a spear, who walks on beams over the pens in which the animals are placed; each animal is killed by a thrust direct into the spinal column. This method looks anything but humane.

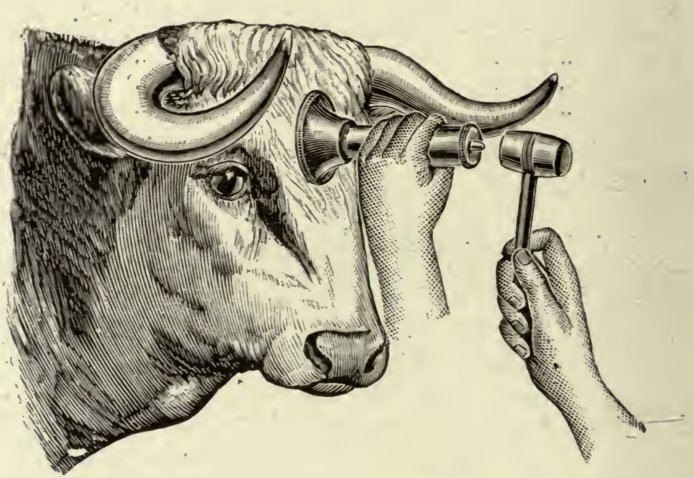

Fig. 1—Method of using Greener's Humane Cattle Killer.

Fig. 2—Diagram showing Track taken by the Bullet into the Spinal Cord.

After the animal has been bled it is flayed, disemboweled, the carcass slung up, and divided from end to end, and dressed.

The manner in which a carcass has been dressed should be noted. If the dressing has been done badly it betokens either that there has been want of skill on the part of the butcher, or what is more frequently the case—that the operation has been performed hurriedly, when the animal has been killed in a moribund condition.

It is most important that the animal should have been properly bled. Imperfectly bled meat is unwholesome and keeps badly, and the flesh is as we shall see later, dark in colour and unduly moist.

A sound, healthy carcass will be well "set" as soon as it is thoroughly cool. The conditions which affect this healthy setting are :—

(*a*) The condition of the animal at the time of slaughter, which includes the nature of the food and the amount of water given prior to slaughter.

(*b*) Atmospheric conditions.

(*c*) The manner in which the animal has been slaughtered.

(*d*) The treatment of the carcass after the dressing has been performed.

(*a*) In regard to the condition of the animal at the time of slaughter. If the animal has been excited, or has undergone great exertion, or has been given too much water, or food which was too moist, the carcass will not set well.

(*b*) If the atmosphere is dry and cold, setting will be favoured, but if the air is warm and moist it will be interfered with.

(*c*) The more thorough the bleeding, the more perfect will be the setting.

(*d*) After dressing, the carcasses should be hung in a cool, airy, covered place, and not too close to each other, in order that the flesh may set well.

If the carcass, after dressing, be placed in an ill-ventilated place, or wrapped in cloths, it will remain moist and flacid, and if the weather be thundery, will quickly turn.

Offal.

In places where carcasses are inspected, the offal should also be available for a like purpose. Under the term offal, in the case of oxen and sheep, the head, feet, hide, and all the internal parts except the kidneys are included; but in the case of pigs, the offal only includes the viscera with the exception of the kidneys, (the head, feet and skin forming part of the carcass.)

The mouth and tongue should be free from blisters and blotches, the hide healthy, hoofs firmly attached to the feet.

The lungs should contain air, *i.e.* portions cut off should float in water, and there should be no evidence of inflammation, tuberculosis or worms.

The heart should be healthy and free from bile-staining.

The liver free from abscesses, firm, not readily breaking down on pressure, and of a rich brown colour.

The liver of a sheep should be examined for flukes.

The spleen should have sharp edges, be of a grey colour externally and dark colour internally.

The stomach should be examined as to its lining membrane, which should not readily peel off. There should be no odour of any drug.

The Inspection of the Carcass as a Whole.

Beef is divided into sides at once, and subsequently into quarters.

Mutton is supplied in whole carcasses.

A well-fed quarter of ox weighs as a rule not less than 150 lbs, that of a heifer weighs less but is usually over 135 lbs, and should not be under.

Sheep as a rule weigh about 70 to 75 lbs, if under 50 lbs they are of too poor a quality to be accepted.

In inspecting beef and mutton the following points should be noticed:—

(*I.*) Signs of age. Age is betokened by bleaching of the ribs, hardness and compactness of the bones and consequent absence of cartilage from the ends of the bones. The vertebræ or chine bones will be less porous and harder in old than in young animals. The condition of the symphysis pubis will reveal evidence of age, if from an old animal, it will have been divided by a saw, and the cut surface of the bones will be smooth; in young animals, the symphysis is cartilaginous and can be cut through with a knife, or if ossified the bone is porous, and gives a jagged surface if sawn through, as distinct from the smooth saw cut of an aged animal. In old sheep the kidney fat will be much veined on the surface, and the back will be of a drab colour, (other signs of age as mentioned for beef will also be present).

(*II.*) Condition of the chest walls. If the pleura has been removed (stripped) this will have been done either to remove the evidence of tuberculosis (in the form of "grapes or pearls", which are the popular terms for tuberculous nodules) or on account of pleurisy, or else to remove blood-stains, or stains from the contents of the stomach or intestines which may have by accident been poured into the chest cavity. If stripping has been practised to hide evidence of disease, the condition of the under-lying flesh, the appearance of fat as well as the condition of the deep lymphatic glands and possibly bones, will expose the fraud. Walley says: "I have found tubercle in the deep lymphatic glands—and advanced and extensive tubercular lesions in the bones of apparently healthy joints of meat."

(*III.*) Examination for evidence of dropsy, or tuberculosis, should be made of the parts where connective tissue is plentiful, such as the flanks, beneath the diaphragm, under the arms and shoulders, and behind and above the kidney fat.

(*IV.*) The carcass of a sheep should be quartered, and the condition of the tissues close to the bones examined. In thundery weather commencing putrefactive changes may often be noted in these situations. The condition of the flesh at the time of the division, and at about an hour later, should be noted; if after the lapse of this time it has not assumed the bright florid colour seen in healthy meat, suspicion should be at once aroused.

(*V.*) Determination of sex is of importance. There are three kinds of animals to be distinguished—the bull, the ox, and cow. A fourth should be mentioned, viz.:—"stag," which is an imperfectly castrated animal, or one in which the operation of castration has been performed late in life.

The first is most muscular, and the muscle fibres are coarser and more stringy; there is less fat than in the ox, the pizzle is much larger, there is less cod fat, the bones are heavier, the shank and arm thicker; in the bull also the neck is furnished with a thick coarse crest, and the muscles of the chest are especially well developed.

The ox is intermediate between the bull and the cow. The arm of the cow is more slender than that of the ox. The presence of the udder in the cow distinguishes the sex; if the hind quarter is seen, the character of the udder will serve to distinguish a heifer from a cow. In the heifer it is firm, elastic and plump: in the cow that has had a calf it is more spongy and flabby.

Of the various joints into which a carcass is divided after being quartered it is only necessary to mention one or two:

The fore-rib does not, as one would infer, include the fore-ribs in the natural position, but includes the six ribs which come after the rib included in the loin. If the carcass is placed in what one may call the "butcher's position," the term appears less anomalous. The middle rib includes four ribs and the "chuck," the 1st and 2nd ribs, making up the total of thirteen ribs. The clod and sticking piece is what is known as the scrag-end or neck. The brisket is between the thin flank and shin, and includes the sternum. The shin is the arm.

Characters of Good Meat.

It is firm and elastic to the touch. Florid in hue in the case of young adult animals, brighter before eighteen months, and darker after six years, but it is never dark red or patchy. A skewer plunged into the flesh should meet with uniform resistance; unequal resistance at different places whilst being introduced, indicates either commencing decomposition or the presence of abscesses. The skewer on being withdrawn should have the characteristic healthy smell of good meat The intermixture of fat between the muscular fasciculi gives rise to a marbled appearance; this marbling should be present. The fat varies in colour from white to straw colour and yellow; feeding affects the colour, rich oil cake deepening it.

In cooking there is said to be a greater loss with yellow fat than with that of a lighter colour, this loss according to "Walley" amounts to from 20 to 30 per cent. The fat should be free from hæmorrhages. Excess of fat in the ox is found in the pelvis and round the kidneys. In the sheep it will be found around the kidneys and on the back, and the absence of a bluish patch between the shoulders at once shows that there is excess of fat. Bone should not exceed 17 to 20 per cent. of the whole. In inspecting meat rations prior to cooking this must be taken into consideration. The marrow should be of a pinkish hue, free from brown discolouration or spots. In the hind legs it should be set twenty-four hours after slaughter in temperate climates, in the fore legs it is more diffluent than in the hind.

There should be no draining from the connective tissue. The reaction of the meat should be acid, if neutral or alkaline, it indicates commencing putrefaction. On cooking, meat loses about 25 per cent. to 30 per cent. Bad meat may lose as much as 40 per cent., the reason being that bad meat contains more moisture than good.

In inspecting meat as it arrives on board ship, or as it is received in a naval establishment on shore, it will be impossible to examine the viscera, so advantage must be taken of the lymphatic glands or " kernels," which should be looked for : in health they are firm, of a light buff colour, slightly moist. There should be no congestion, inflammation, pus, caseation, or calcification ; the glands will often afford evidence of tubercle when there are no signs of this disease elsewhere.

Those most easily to be found are the Sternal, Suprasternal, Dorsal (along the sides of the ninth and tenth dorsal vertebræ) ; Lumbar scattered about in the fat immediately behind the kidneys ; the Sacro-lumbar, in the situation suggested by their name ; Mammary at the base of the udder in the cow ; Deep inguinal, deep in the inner side of thigh, and the Superficial inguinal on the outside of the flank.

Meat not of the Description Represented.

Beef must not be the flesh of horse, mule, or ass, all three of these being, in the eyes of the law, horse-flesh.

Mutton must not be goat-flesh, and lamb not the flesh of kid or dog. Dog flesh has been known to be offered for sale as veal, the flesh in such cases being that of a large dog. If a goat or dog were exposed whole there would be little or no difficulty in detecting the fraud, but if, as is usually the case when fraud is attempted, the head and feet in the case of goats, and the head, feet, and legs as far up as the knees and hocks in the case of dogs, are removed, detection is not so easy. The vertebræ in the goat are more prominent, and the skin is darker *(i.e.,* the covering after removal of the pelt), the flesh is darker than that of the sheep and, as a rule, less fat, and gives out a characteristic odour on heating. Therefore, in countries where goats abound the carcasses of sheep should have the feet attached.

Dog-flesh may be distinguished from the flesh of the calf and lamb by the bones being more completely ossified, so that the epiphyses cannot be made out. In the case of calves additional distinction is that the joints are much larger than in the case of dogs, and moreover, dog-flesh always has a quite distinct odour.

The carcass of a horse can be distinguished from that of an ox by the following means : a horse has eighteen pairs of ribs and an ox only thirteen, when fraud is attempted the extra five pairs are consequently removed. The shape of the ribs is a point of distinction also, in the horse they are more arched and narrower than in the ox. The ribs of the ox are larger and broader than those of the horse, their breadth is greatest and their curvature least in the lower half. In the ox there is a true diarthrodial joint at the junction of all the eight true ribs with the costal cartilages, in the horse the chrondro-costal articulations are immovable. The flesh has a different feel, the fibres of horse-flesh are the more stringy, and after a lapse of a few days the flesh becomes soapy to the touch and possesses a peculiar sickly odour, the fat is softer, more diffluent and more of a yellow colour than ox fat; where fraud is intended, as much of the fat as possible is removed and firm beef fat attached in its place. The ends of the bones and attachment of muscles are more marked in the horse than the ox. The viscera if seen are characteristic. The heart of the ox is pointed and contains some fat in the interventricular furrow, whereas the heart of the horse is more rounded at its apex, and there is less fat in the interventricular furrow. It does not contain a bone (the os cordis), which is present in the heart of the ox. The liver of the horse has three distinct lobes, a right, left, and middle, and a fourth or supernumerary lobe, and there is no gall bladder. In the ox and sheep the liver is not divided into lobes, but has one small lobe at its upper and posterior part, and there is a gall bladder. The kidneys in the horse are not lobulated, the right one is more or less heart-shaped and the left more quadrilateral. In the ox the kidneys are lobulated. The tongue of the horse is broad at its free extremity, and its surface smooth, that of the ox is pointed and its surface rough. The tongue of the horse also is long, and has a well marked median raphe; on either side of this raphe, towards the root, is a well marked eminence containing papillæ in recesses—papillæ circumvallatæ. In the ox these circumvallate eminences are wanting, and, instead, we find two diverging rows of papillæ shaped like the letter V with the open part pointing towards the root of the tongue, each row contains from eleven to thirteen papillæ.

Immature Veal and Lamb.

This is recognised by the pallor of the flesh, softness of the tissue and excess of moisture. If unborn animals are exposed for sale, they may be distinguished if the feet are attached. The horn of the hoof in the unborn being so soft that it can readily be indented with the nail, and it is also of a yellow colour.

Lamb and veal are occasionally "blown" to produce an appearance thought to be attractive. This is a disgusting practice, which consists in inflating the loose cellular tissue with the breath by means of a blow-pipe, and then injecting or blowing melted fat over the parts.

Refrigerated Beef or Mutton.

This is not issued in the Navy except in hospital ships and hired transports, but as such enormous quantities of refrigerated* and frozen meat are annually imported, it is necessary to describe the character of the meat.

Refrigerated meat is kept in cool chambers, the temperature of which is maintained at about 36°F. by means of cold air which is caused to flow through them. The meat is cold and clammy to the touch, the fat is of a pinkish hue, and a pinkish hue pervades the whole carcass, the shanks are bruised and the flesh lacks the bright colour of fresh killed beef. After removal from the refrigerating chamber it should be quickly used, as it keeps badly. If the meat has been placed in the cool chamber before it has had time to cool, it is apt to become a little decomposed in parts farthest removed from the surface, and a condition described as bone stink is found to exist. These remarks apply more especially to frozen meat. The Commissioners on Tuberculosis (1897) recommend that in all foreign dead meat, where stripping of the pleura has been practised, the carcasses shall be seized.

Frozen meat always feels cold and damp to the touch after it is thawed; the fat is of a dead white colour, and the flesh is of a pink tinge from changes which have occurred in the hæmoglobin and consequent diffusion of the colouring matter. Frozen mutton is always superior to frozen beef, because mutton can be frozen in whole carcasses, while beef, because of the greater size, cannot. Frozen mutton has always a dead, dirty appearance, and lacks the bloom noticeable on the carcasses which are fresh killed. It is always cold and damp to the touch. Care should be taken to see that the carcasses are in good condition right through, as often apparently good carcasses are found to be more or less decomposed when cut through at the hip and shoulder. It has recently been shown that the process of prolonged refrigeration or exposure to extremely low temperature for several weeks is fatal to various forms of cystercerci met with in meat.

Salt Provisions.

Salt beef, salt pork, and preserved mutton are issued as part of the *sea-service* dietary, that is to say, not *in harbour*, unless it is impossible to obtain fresh meat. When the ship's company are on salt provisions, salt pork is issued every other day, and on those days on which it is not issued, salt beef and preserved mutton are issued by turns.

The Merchant Shipping Act of 1892 requires that pre-

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*At the present time there are 123 vessels engaged in bringing frozen meat to London, and these vessels have a carrying capacity of 4,529,400 carcasses. The great majority of these carcasses come from New Zealand and Australia, the rest from the River Plate.—*The Hospital* 20th November, 1897.

served meats and other articles of diet required at sea shall be inspected by an officer of the Board of Trade, as to their fitness when carried by ships trading or going from any port of the United Kingdom through the Suez Canal, or round the Cape of Good Hope or Cape Horn. No ship is allowed to sail without a certificate that the provisions are fit for issue. Meat preserved by salting is of less nutritive value than meat preserved by the exclusion of air, as is the case with Australian preserved mutton. The nutritive value of salt meat is estimated at being two-thirds that of fresh meat. It cannot be eaten on successive days in the way that fresh meat can, hence the alternation of preserved meat arranged for in the Admiralty dietary.

Salt meat is of higher nutritive value than such statements as the following would lead one to suppose. In an account of the second Grinnell Arctic Expedition, Dr. Hayes, who served in the "Advance," speaks of the effect which salt meat had upon the sledge-dogs previously unaccustomed to such a diet. "They could not eat it except in small quantities, and the salt of the meat together with the cold and darkness operating upon their feeble bodies . . . ultimately destroyed nearly every animal which Dr. Kane took with him from South Greenland or afterwards procured."* In the case above quoted no doubt the meat was of inferior quality and badly salted. Salt provisions are issued on much fewer occasions than was the case before the introduction of steam. I have known cases, and they are by no means exceptional, where men welcomed salt meat as a pleasing variety, after having been living on fresh meat for some time.

Beef and pork are preserved for the Royal Navy by a process of pickling, which consist in rubbing in salt, and storing the salted pieces in a bin, the beef being in 8-lb. pieces cut from fore-quarters, flanks and briskets,† and the pork in 4-lb. pieces. White salt being occasionally thrown between the layers. It is left for four days in the first bin, and then the meat is transferred to another bin, packed with salt as before but in such a way that the top pieces in the first bin become the lowest in the second. The salt acts as a preservative chiefly by the abstraction of water by osmosis, the extracted water shows itself as brine which runs from the bins, and is then boiled and mixed with pickle to the extent of one-half, which is thrown over the beef, at least twice a day, the top pieces each time being covered with

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*American Journal of Med. Science, July, 1859. Pp. 114-118.

†On the Australian Station where salt-beef is purchased locally, there is no clause in the contracts confining the portions employed to pieces cut from the above-mentioned parts.

white salt; after remaining for four days in the second bin, it is weighed and packed into casks, and a proportion of bay-salt and saltpetre mixed together is distributed between the layers of meat as it is packed. The Admiralty directs that coarse and prime pieces shall be packed in due proportion, and when it is boiled ready for use on board ship, it is to be delivered out to the messes by pricking fairly for it (which means that the pieces are to be drawn like numbers in a lottery and not selected). When the cask is packed it is filled up with "pickle" consisting of 4 lbs. of white salt to one gallon of cold water.

The quantity of white salt used in the curing process is 50 lbs. for a barrel of 300 lbs., and 36 lbs. for half-hogshead of 200 lbs., the quantity of bay-salt for packing is 60 to 70 lbs. per barrel, and 45 to 55 lbs., per half-hogshead, and of saltpetre 3 ozs. and 2 ozs. respectively.

Bay salt is a dark-coloured form of salt containing iodine, imported from France, Spain and Portugal, obtained from sea-water by evaporation, which is conducted in shallow pools called salt-pans. (French salines).

The salt meat must always be steeped for at least two hours before being put into the boilers, and one hour and a half is allowed for cooking.

In inspecting salt meat, it should be noticed whether the brine is sweet, and whether the meat shows evidence of decomposition. Meat partially decomposed at the time of salting will still show signs of putrefaction more or less advanced; if it has been prepared from old meat it will still show signs of toughness and absence of fat. The presence of cysticerci or other parasites should be looked for, since the encysted forms of animal life are known to be very resistant to even prolonged salting. It is forbidden by Admiralty Instructions to allow the water in which salt meat has been boiled to be used in any way by the men on account of its being so unwholesome.

Australian preserved mutton is prepared by cooking in tins, after it has been boned, the tins, before commencing the cooking process, being closed, except at a small vent-hole; the cooking and sterilisation is effected by partly immersing the tins in a heated solution of Calcium Chloride. Calcium Choride is used (as in Thresh's Disinfector) as a means of raising the temperature of water above that (212°F.) at which it boils at ordinary atmospheric pressure after being kept at a temperature of between 212° and 230°F. for four hours, during which time some of the moisture present in the meat, and nearly all, if not all, the air in the tin is expelled, the tin is sealed with solder, allowed to cool, painted and labelled. Any air which was present at the time of sealing the tin will, by reason of the high temperature, be sterile, and on cooling, the pressure exerted by it is so slight that the shape of the tins must be more or less concave on the upper and under surfaces. If the tin shows signs of bulging it is certain that the air had not been all expelled, and that it had not been rendered sterile, so that decomposition, with the evolution of gas, has occurred.

The unavoidably prolonged cooking and over-heating of the meat causes some disintegration of the muscle fibres, hence the stringy appearance of preserved mutton.

Another method of preserving meat in tins is to withdraw the air and replace it by a mixture of sulphur dioxide and nitrogen.

Preserved meat being more nutritious than salt meat, three-quarters of a pound is issued as against one pound of salt-beef or salt-pork.

The reduction in weight effected by the removal of the bone, and the fact that it is cooked and ready for use, render it invaluable for detached service or for campaigning; with the exception of the weight of the tin every ounce carried is available as food, an important consideration where no unnecessary weight is allowed.

Cooking acts by coagulating the myosin and albuminoids in meat and converting the connective tissue into gelatine, also by causing partial disintegration of the muscle fibres renders mastication easier, and enables the gastric-juice to penetrate more easily. Parasites are killed by cooking, if the process be complete. By cooking, water is lost and also a certain amount of fat. The total loss in weight should not exceed one-fifth to one-fourth for boiled meat, or about one-third for roast meat. Meat containing an excess of moisture, and therefore of inferior quality, as we have said before, loses much more on being cooked.

If roasting or boiling be the method of cooking adopted, the joint should first be exposed to a sufficiently high temperature (212°F.) to coagulate the albuminous matter on the external parts, which serves as a skin for the retention of the juices of the meat. In stewing, which is cooking at a comparatively low temperature over a water-bath, the juices are extracted, which would mean a considerable loss in nutritive value, but if served with the meat as is usually the case, stewing forms a very good method of cooking.

If the cooking be conducted at too high a temperature (over 170°) the tissues shrink, become hard and tough and not easily digested. The best temperature at which to boil meat is between 160°F. and 170°F. If the interior of the joint does *not* attain a temperature of 160°F. it will be underdone,* if it reaches 160°F. or upwards it will be completely cooked.

Boiled meat is easier of digestion; roast is more palatable.

Meat partially decomposed through having been kept too long. Meat of this description shows loss of elasticity, readily tears, and resistance to the knife is uneven. The part exposed to the air may be light coloured, and, at a later stage, greenish, or it may be dark, hard and dry. The reaction will be either neutral or alkaline.

In case of accident where an animal has suffered from fracture, dislocation, bruises or wounds, these lesions will be seen on the carcasses.

If the animal is seen before death, and killed, and efficiently bled, the flesh is fit for food, provided contused and lacerated parts are removed; but in the case where an animal has survived long enough to develop fever, pyæmia, or septicæmia, the flesh will be deteriorated and unfit for food.

Animals trampled on will generally show much bruising, and also the signs of death from asphyxia, in which case, the carcass will be quite unfit for food.

If the animal is much bruised and nearly suffocated, but not dead and bleeds badly, its carcass should also be condemned. In death from drowning the carcass will be unfit. Lightning, as a rule, unfits a carcass for food, simply because the animal is not as a rule seen in time for it to be properly bled.

In the case of an animal burnt and not killed the carcass may be employed for food, if after the accident life has not been prolonged sufficiently to allow of a febrile condition, or the absorption of pus in the case where there is extensive suppuration (provided the animal is properly bled and affected parts removed).

Parturient Animals. Carcasses of animals in the parturient state are not condemned as a routine practice, whether killed either immediately before, after, or during parturition, unless the animal has become exhausted, or there is evidence of some abnormal condition, which has caused the flesh to become œdematous, or there is infiltration of pus or extensive hæmorrhage, in such cases the meat will not set and be so sodden and unsightly as to at once indicate condemnation.

Poisons. Inorganic poisons chiefly produce local effects. Phosphorous produces general symptoms, such as rapid fatty

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* *Vide* note on experiments on cooking conducted by Woodhead, quoted in respect to Tuberculous meat.

degeneration of the coats of blood vessels, leading to general extravasation of blood. The blood itself is much altered and the tissues are seen to be phosphorescent in the dark. Needless to say the carcass should be condemned. Walley says that in his opinion "Inorganic poisons (with the exception of Phosphorous) are never absorbed in sufficient quantity to render the flesh of the poisoned animal nocuous."

Of inorganic poisons those of a narcotic nature are the most harmful, as bringing about death in a manner similar to suffocation. Organic poisons are most harmful when taken in the plant form.

Walley mentions the fact that animals killed for food with arrows poisoned with curara, can be eaten with impunity, showing that the poison is not absorbed in sufficient quantity to be harmful.

A sheep may die from getting on its back, and death results in these cases from suffocation produced by tympany, which has been caused by fermentations of the contents of the rumen, the back in such a case will show evidence of hypostatic congestion, and the condition of the carcass will depend on the length of time the animal has been in this unnatural position.

The diseases which render the flesh of Bovines totally unfit for food are as follows:—Cattle Plague or Rinderpest, Epizootic Pleuro-Pneumonia, Anthrax, Symptomatic Anthrax, Tuberculosis, (Actinomycosis cannot with certainty be classed in this list) and lastly Rheumatic Fever or Joint-ill. Sheep are liable to all the above diseases, if we except Epizootic Pleuro-Pneumonia, which is essentially a disease of cattle, and they are subject in addition to sheep-pox or *Variola ovina*.

The presence of *Cysticerci* also renders the flesh unfit for food.

In swine, swine-fever and swine erysipelas* unfit the flesh for food, also such diseases as Anthrax, Tuberculosis § and parasitic diseases such as are produced by the presence of *Trichina spiralis* or *Cysticercus cellulosæ*.

Cattle plague is a highly infectious and contagious disease, which happily, owing to the "stamping out system," has not been met with in England since 1877, but in 1865 and 1866 was the cause of great loss to this country; in February,

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*In England the term Swine Fever is generally understood to include Swine erysipelas.

§ The Commissioners on Tuberculosis, 1897, recommend that in the case of Tuberculosis in the pig, which has a greater tendency to become generalised than in bovine animals, the presence of any tuberculous deposit should render the whole carcass and organs unfit for food.

1866, the number of deaths from it had reached the enormous number of 18,000 weekly, and it was then that the stamping out was brought into force, with such beneficial results.

The Stamping out System consists in the carrying out of an Act of Parliament by which the notification and slaughter of all diseased animals is compulsory, and also the proclaiming of districts in which cases have occurred as infected areas, out of or into which cattle may not be moved until permission is granted.

Cattle Plague is characterised by the following signs and symptoms ; the animal commences to be "off its feed," it is listless, the ears droop, and a discharge is seen from the eyes, nose and mouth, it shows evidence of pain, there is fever, and pustules form on the mucous membrane of the mouth and nostrils, preceded by redness, there is diarrhœa, intense prostration, shivering, often bloody urine, and if examined the urine is always found to be albuminous. The eruption is not confined to the mouth and nostrils, but is often seen upon the back, and inner aspect of the thighs. There is an offensive odour emitted from the body. If the disease is far advanced the flesh becomes emphysematous, is dark in colour and of offensive odour, but if the animal be killed early, nothing remarkable is noticed in the flesh. A cattle dealer once told me that he met with three cases in one cow-keeper's cowshed, in which the cases occurred one after another at intervals of about a week, in each case he recognised the disease by the diarrhœa, intense prostration, cessation of rumination and alvine flux, and in each case he recommended immediate slaughter (with a view to the *carcasses being sold for beef!!*), which recommendation the dairyman in each case neglected, with the result that he lost all the three cows, which were in the same shed. Had he acted on the advice of the dealer, he would have saved £25, but his loss was the public gain.

The disease is both infectious and inoculable, and it would seem that where inoculation was practised, the incubation period was shorter, and the disease less violent than when contracted by infection.

Epizootic Pleuro-Pneumonia is a disease which is highly contagious, yet the incubation period is said to be no less than 30 days. An animal suffering from it has a peculiar dry cough, shows difficulty in breathing, high temperature, there is arching of the back, and all the signs of pain evidently produced by the pleurisy which accompanies the pneumonia.

Animals are said to contract the disease by actual contact with an affected animal ; merely using the same sheds where the animals had not come in contact, is said not to have given rise to the disease. As one would expect, the flesh is dark and gives all the appearances of meat in which bleeding had not been efficiently performed. The viscera present the usual symptoms of pneumonia, and there is frequently a considerable amount of fluid in the pleural cavities.*

Anthrax is an extremely fatal disease, which kills very rapidly, death frequently occurring after exposure to the contagion in 36 to 48 hours. Endemic in certain places, such as in the neighbourhood of Lake Van in Armenia and in certain parts of France and Germany, Anthrax reaches England as spores attached to the fleeces. Crookshank mentions an interesting case in which an outbreak was successfully traced to the waste wool from a wool factory at Yeovil, where infected wool had been imported. The factory washings were brought to a farm on the banks of the River Yeo, by means of an overflow, the spore bearing *Anthrax bacilli* carried in the washings being left behind when the flood subsided; animals grazing on the land thus infected, developed the disease. Other cases are also mentioned by Crookshank, where animals contracted the disease through grazing on land where other animals which had died through anthrax, were buried. All herbivorous animals and rodents are susceptible; swine which for a long time were regarded as enjoying immunity from the disease, are now known to be susceptible to anthrax. Adult rats and Algerian sheep are not very susceptible, and cats and dogs are only infected with great difficulty.

The symptoms of the disease are these: the animal looks dull and apathetic, ceases to feed, shows evidence of thirst, appears to be extremely tender to the touch, and breathes with difficulty. After death the flesh is found to be dark coloured, the blood is of a dark colour and does not clot, extravasations of blood are noticed in the muscles and various organs. The spleen is enormously enlarged, has smooth rounded edges, it is extremely soft and very dark coloured. In a doubtful case examination of the blood will soon reveal the presence or otherwise of the disease, by the presence or absence of the *Bacillus anthracis*, which is from 5 to 20 μ long and 1 to 1·25 μ broad, it has square cut ends, produces spores on exposure to air, and is non-motile.

In *Symptomatic anthrax* the bacillus is motile, has rounded ends and is shorter and narrower. *Symptomatic anthrax* or quarter evil is known in France as *Charbon symptomatique*. This shows itself in emphysematous swelling

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*No disease shows more markedly the beneficial results of the stamping out system; in 1890, there were in England 36 counties infected, and 2,057 cattle attacked. In 1894, there were only two counties infected, and only 15 cases of Pleuro-Pneumonia.

of the hind-leg, as a rule in young cattle, under a year old. The affected animal is lame, ceases feeding, shows evidence of fever, and dies in about two days.

Protective inoculation appears to be unsuccessful.

Tuberculosis exists largely amongst bovines, but it is chiefly amongst dairy cows* that it is met with, the artificial conditions appertaining to stall-fed milch cows in towns tends to spread the disease. The cows are often kept in ill-ventilated sheds, the temperature of which is in consequence too high, and there is insufficient cubic space (the Carlisle Urban District Council, as a means of preventing bovine tuberculosis, has decided that there must be at least 800 cubic feet for each cow). Cows in towns also are drained of milk over far too prolonged periods, which like in-breeding acts as a pre-disposing cause to tubercle. Opportunities also are not wanting in cow-sheds for the spread of the disease by contact, as occurs when the animals feed and drink out of the same mangers and troughs, and we must not overlook the fact that a cowman suffering from tuberculosis might be the means of infecting the cattle.

Tuberculosis is not now thought to be congenital, and that heredity plays a very minor part in spreading the disease, is shown by the fact that tuberculous cows, for the most part, bring forth healthy calves, and if these calves are fed entirely on boiled milk, and separated from their mothers immediately after birth, they remain healthy; they may acquire it by infection from a tuberculous udder. It has been clearly proved that tuberculosis can be produced in calves from tubercle in man and there is little doubt that conversely tuberculosis in cattle may be conveyed to man, and produce a disease indistinguishable from the disease ordinarily met with in men.

Animals affected with Tuberculosis are often spoken of as "wasters" or "mincers." The disease in the live animal may be recognised as follows :— There is usually emaciation, the coat is staring, skin dry and harsh, breathing difficult, there is cough, diarrhœa, and the milk is thin ; but occasionally

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*The last commission on tuberculosis published the following figures from the returns of animals slaughtered and examined at Leipzig in 1895, shows very clearly how much more prevalent tuberculosis is amongst milch cows than it is amongst oxen and heifers.

Description of animals.	No. slaughtered.	Per cent. found tuberculous.
Oxen	8,454	28·14
Heifers	1,071	20·35
Cows	9,303	43·51
Bulls	4·090	23·83
Total cattle over one year old ..	22,918	33·24

animals are slaughtered which showed no evidence in life of the disease, but are found after death to be tuberculous. The udder is often the seat of tuberculous nodules, and in the carcasses tuberculous disease is shown in disease of the bronchial glands, caseous masses in the lungs, numerous tuberculous masses (grapes) attached to the pleura, and also in the peritoneum, the liver, kidneys and brain. Tuberculous ulceration is said to be less common in cattle than in swine. The fat of affected animals is wet and lacks the suety firmness met with in the healthy carcass.

The question of allowing as food supply the flesh of animals affected with Tuberculosis in which the lesion is strictly limited, is a vexed one and often difficult to decide, but in the case where the disease is extensive and its manifestations marked there is no difficulty; in this case there is nothing to be done except to condemn the whole carcass and ensure its destruction.*

Various experiments conducted by Woodhead to ascertain the effect of cooking upon meat, showed that in the case of large joints, whatever the temperature on the surface might be, in the interior of the joints it seldom reached 60 degrees C., and that if reliance was to be placed on cooking, the joints should not be more than 6 lbs. in weight, so that we may say that joints which are not heavier than 6 lbs may be used for food with safety provided the cooking has been complete.

The Commissioners on Tuberculosis appointed in 1890 issued a report in 1895, and in it they stated that :—

"Provided every part that is the seat of tuberculous matter can be avoided and destroyed, and provided that care be taken to save from contamination by such matter the actual meat substance of a tuberculous animal, a great deal of meat from animals affected by tuberculosis may be eaten without risk to the consumer."

The Commissioners appointed in July 1896, issued their report in 1897.

They recommend that the entire carcass and all the organs should be seized :—

(*a*) When there is miliary tuberculosis of both lungs;

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*In regard to experiments carried out with tubercle bacilli in milk, Professor Foster has found that the time required to destroy them varies with the temperature, thus—

With	4 hours	exposure	55	degrees	C.	is sufficient.
,,	1 hour	,,	60	,,	,,	,,
,,	15 minutes	,,	65	,,	,,	,,
,,	5 ,,	,,	80	,,	,,	,,
,,	1 ,,	,,	95	,,	,,	,,

(*b*) When there are tuberculous lesions on the pleura and peritoneum.

(*c*) When tuberculous lesions are present in the muscular system or in the lymphatic glands embedded in or between the muscles.

(*d*) When there are tuberculous lesions in any part of an emaciated carcass.

If the carcass be otherwise healthy it is not condemned but every part of it containing tubercle shall be seized when:—

(*a*) The lesions are confined to the lungs and lymphatic glands.

(*b*) When the lesions are confined to the liver.

(*c*) When the lesions are confined to the pharyngeal lymphatic glands.

(*d*) When the lesions are confined to any combination of the foregoing but are collectively small in extent."

The new conditions required are more clearly defined and less exacting than those issued in 1895, but there would still seem to be a certain amount of danger of infecting otherwise healthy meat with the knife used in the process of cutting it up, which is liable to divide unsuspected tuberculous glands and so spread the virus, but if we consider that the parts so infected must of necessity be on the surface after the section is complete, the danger becomes less real, for in the cooking process such parts will become sterile.

In Prussia the authorities regard the flesh of a tuberculous animal as dangerous when the meat contains tuberculous nodules, or the affected animal has become emaciated; and they regard the flesh as usable if the tubercle is limited to one organ, and the animal shows no emaciation.*

In France they condemn the flesh when there is general tuberculosis, or where the greater part of an organ is affected, or where there is tuberculous disease of the chest wall or abdominal cavity.

At the fourth Congress of Tuberculosis, held in Paris from 27th July to 3rd August, 1898, Professor Nocard, of Alfort, amongst other statements in the presidential address said, "That it is now known that not one of our domestic

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*In certain towns in Germany there is an institution known as the Freibank, where the meat from animals only slightly affected by tuberculosis is sold under the supervision of competent meat inspectors, some of the meat being that which has been sterilised by steam for half an hour at a temperature of 100 deg. C., and some being sold raw, but in both cases the meat is sold officially guaranteed against risk of infection. There is said to be a great demand for this meat, which is sold at a cheap rate.

animals is refractory to tuberculosis in the absolute sense of the term. That the great hope for the future concerning tuberculosis lies in prophylaxis. It is the duty of the medical profession to continue preaching in season and out of season that tuberculosis is preventable, arising in the immense majority of cases from contagion, which can easily be guarded against."*

In the case of bovine animals he pointed out "that the isolation of diseased animals at once arrests the spread of the disease.

Bang, of Copenhagen, at the same congress gave the following statistics :—

Percentage of animals in slaughterhouses found to be tuberculous—

GERMANY.	Baden		3·67
,,	Bavaria		5·0
,,	Hamburg		8·56
,,	Prussia		12·7
,,	Saxony		27·5
,,	Zurikan		37·5
AUSTRIA.	Vienna		1·3 to 1·8
FRANCE.	Toulouse		9·28
,,	Brie and Beauce (*Nocard's Statistics*)		25·0
HOLLAND.	Amsterdam		8·12
,,	Rotterdam		7·0
ENGLAND.	Manchester		29·4
DENMARK.	Copenhagen	1895	29·66
		1896	25·31
		1897	26·87

In regard to reactions to the tuberculin test there were—

In Bavaria, 1895 & 1896	37·2	*p.c.*	*positive*	*reactions.*
,, Vienna	39 to 43	,,	,,	,,
,, Strebel	41 to 52·5	,,	,,	,,
,, Copenhagen	28·8	,,	,,	,,
,, Sweden	42·2 46·9	,,	,,	,,

At the suggestion of Bang, "the Danish Government, in 1893, passed an enactment enjoining owners to submit bovine animals to the tuberculin test, and to isolate, as completely as possible, those which reacted." "Cattle from abroad are placed in quarantine, and tested with tuberculin; animals which react are slaughtered."†

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* *B.M.J. Epitome*, p. 25. 13th Aug., 1898.

† *B.M.J. Epitome*, p. 26. 13th Aug., 1898.

Actinomycosis is a disease of animals, communicable to man, and attended with grave symptoms, by some held to be of such gravity as to necessitate the condemnation of animals suffering therewith as totally unfit for food, as in the United States of America, though as far as I am aware no case has been recorded where man has contracted the disease through the ingestion of meat infected with actinomycosis, and there would probably never be any necessity for condemning a carcass affected therewith, unless the constitutional disturbance had been sufficient to give rise to deterioration of the flesh. The cause of the disease is the ray-fungus which is epiphytic upon certain cereals, more especially barley.

In animals the disease shows itself in the form of tumours in the upper and lower jaw when it is known (in Australia and America), as lumpy jaw; we meet it also as an interstitial glossitis, which leads to a condition known as "wooden tongue" where the tongue is enlarged and hard, also as tumours of the head and neck and various parts of the body, known as wens and sitfasts.

It is met with in the lungs, larynx, œsophagus, and intestines. Animals are thought to become infected with the ray-fungus through wounds of the mucous membrane, skin, or through carious teeth, and the awns of barley have frequently been found in the abscess cavaties resulting from the growth of the fungus. • Animals grazing on land reclaimed from the sea, or in river valleys and marshes, are said to be peculiarly liable to the disease, and the disease has been met with by Crookshank in Norfolk, Essex, Herts, Cambridgeshire, and Middlesex.

In the centre of the lesions of actinomycosis which are as a rule honeycombed in appearance, is some yellowish pus, in which, with the aid of a microscope, the characteristic arrangement of clubs is seen usually in rosettes or resembling the capitulum of a composite flower.

Joint-ill, or Joint-felon, is a term employed to designate two distinct diseases, one of which is acute rheumatism, and the other a septic arthritis, the result of blood-poisoning following omphalo-phlebitis met with in recently born lambs and calves. Walley, with characteristic sarcasm, says that "the existence of such lesions emphatically warrants the condemnation of the flesh, and such carcasses should be especially sought after by those responsible for the proper conduct of establishments in which potted delicacies are prepared." In life, animals affected with joint-ill are noticeable by their lameness, or inability to rise.

Sheep-pox is a disease of sheep very similar to small-pox in man. It is a vesiculo-pustuar eruption accompanied by fever; when first seen it resembles flea-bites, which soon become papular, then vesicular, and finally pustular. The wool of affected sheep readily comes off. The disease is met with in the discrete and confluent forms, which are respectively mild and severe. The eruption is often to be seen in the mouth. Inoculation against human small-pox was at one time practised with the lymph from sheep-pox vesicles, and the results were said to be satisfactory. The meat of animals suffering from this disease, is soft, wet, and pallid, it has a disagreeable odour, and should be condemned as unfit for food.

The diseases of Swine which in common with other animals render the flesh unfit for food have already been enumerated, and only those peculiar to pigs need be again described, these are :—

Swine Fever or Pig-typhoid, and Swine-erysipelas or Swine-Measles.

Swine-fever is a highly contagious and very fatal disease, with an incubation period of from two to seven days. It is recognised in the live animal by refusal of food, redness of the eyes, shiverings, thirst, drowsiness, unsteadiness of gait, the result of partial paralysis of the hind quarters. At first there is constipation, but later there is diarrhœa, with blood in the dejecta. Cough is present where the lungs are implicated. There is usually redness of the skin, which may be uniform or merely in patches, and enlargement of the inguinal lymphatic glands is generally found.

After death, the lungs, spleen, and liver are found congested, hæmorrhages have taken place into the kidneys, there is redness of the intestines, signs of acute inflammation going on to ulceration of the colon and ileo-coecal valve ; the ulcers are often ochre-coloured and may vary considerably in size, the lungs in addition to congestion frequently show signs of lobar pneumonia, and there is often evidence of peritonitis.

Swine fever, or pig-typhoid, is often known by the name "soldier ;" this is derived from the characteristic reddening of the skin. In the carcass, this should be carefully looked for, as the reddening in pig-typhoid persists after scalding and scraping. The redness is not confined to the skin but the underlying fat is reddened also. The flesh has an offensive odour, and is flabby, pale and wet.

Swine-measles or swine-erysipelas, as we have already stated, is, in England, classed under the term "swine fever." The symptons are very similar—lassitude, cessation of feeding, drooping of the ears, thirst, shiverings; at first, constipation; later, diarrhœa, and, finally, a frequent termination in convulsions. The difference which is supposed to exist between this disease and pig-typhoid is that in the former there is no ulceration of the intestines, and in pig-typhoid there is; whilst, according to others, in swine-measles there are often found ulcers of considerable size in the neighbourhood of the ileo-coecal valve.

Swine were for a long time considered to enjoy immunity from anthrax. Crookshank has shown that this is not the case, and pigs are now included under the anthrax order of 1886.

Quinsy in swine is attended with difficulty of breathing, pain in swallowing, and refusal of food. There is a large amount of swelling of the throat, with œdema, which occasionally goes on to suppuration, and a pyæmic condition results, with secondary deposits in different parts of the body and in the internal organs. It is in such cases that the flesh is unfit for food, and where the flesh is changed in appearance from the effect of prolonged fever it is also unfit.

Parasitic Diseases.

There are two varities of tape-worm met with in the encysted form in the flesh of the ox and the pig. In the ox we find the *Cysticercus bovis,* which consists of the scolex and a cystic expansion of the *Tænia mediocanellata.* If such meat is eaten imperfectly cooked, the cysticercus loses its cyst on reaching the bowel, and becomes attached to the wall of the intestine, where it grows by the development of numerous segments or proglottides from its caudal extremity, these proglottides increasing to such an extent (1,200 to 1,300) that the mature tape-worm is often 20ft. in length. Ova are developed in the proglottides, which are expelled from the intestines, and if they reach a herbivorous host, the embryos escape from the shells of the ova and travel from the intestine through its walls to the muscles or other tissues of the host, become encysted, and the cycle is complete.

The flesh of animals containing cysticerci should be condemned as totally unfit for food, but as we have already mentioned, it has been recently asserted* by Ostertag on good grounds that the process of prolonged refrigeration, *i.e.,* for 21 days and upwards, is fatal to cysticerci, evidence being that they dissolved on performing artificial digestion—a process which, had they been alive, they would have resisted; also that on ingesting considerable quantities of such meat and employing drastic measures to secure subsequent evacuation,

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*Journal of State Medicine, February, '98, page 81.

no trace of tape-worm was found in the stools. Frozen meat affected with cysticerci, however, might be harmless, but could not fail to be unpalatable. *Tænia mediocanellata* is not uncommon in the Royal Navy, it may be recognised by the shape of its head which is about 1-15th of an inch in diameter, has four large suckers, but no rostellum or hooklets.

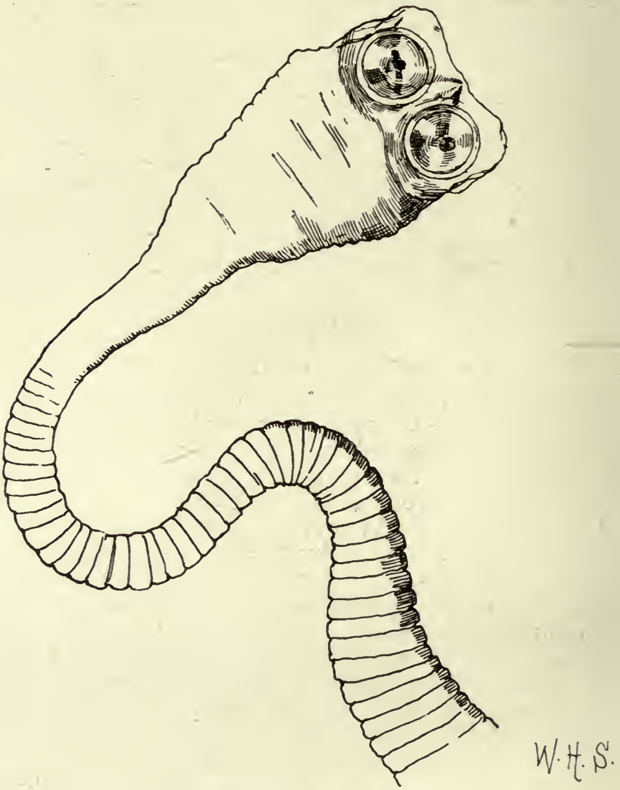

Fig. 3—Tænia mediocanellata.
Magnified about 15 diameters.

The parasite is met with in Abyssinia and other parts of Africa, in Australia, India and America.

The other form of cysticercus which is frequently met with, is the *Cysticercus cellulosæ* which is found in pork; pork infested with cysticerci being known as measly pork. It occurs in various parts of the body such as the liver and brain, but most frequently in the muscles between the fibres.

The cysts are a little larger than those of *Cysticercus bovis,* and are from 1-3rd to 3-8ths of an inch in length. It is asserted by some that the bladders or cysticerci may be felt in the live animal beneath the tongue, or in the loose folds beneath the tail. The head is about 1-40th of an inch in diameter, has a double row of 26 hooklets, which surround the central eminence or rostellum. The hooklets are of two kinds, long and short, which are flattened from side to side, and placed alternately. The tape-worm is from 7 to 10 feet in length, and may have as many as 800 segments.

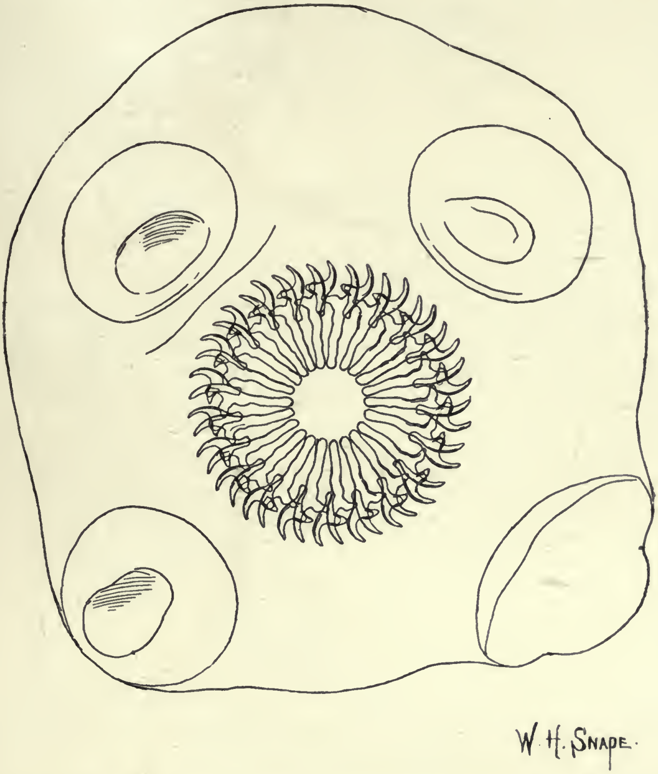

Fig. 4—HEAD OF *Tænia solium.* From a Cyst of *Cysticercus cellulosæ.*
Multiplied about 143 diameters.

The ova of *Tænia solium* are spherical 1-700th of an inch in diameter, the shells thick with radiating lines, and the contained embryo in each case has 6 hooks. The ova of *Tænia* *mediocanellata* are oval, they possess, like those of *Tænia solium* thick walls with radiating lines, but they are narrower and longer than the ova of *Tænia solium*.

Trichina spiralis belongs to the class of Nematode worms; it gives rise to the disease known as trichinosis, a disease more common in Germany than elsewhere. The trichina spiralis infests cats, rats, mice and pigs, and it is in its relation with pigs that it is of interest to us. In the pig it is met with in the encysted form, coiled up in minute cysts 1-78th part of an inch in length by 1-130th part of an inch in breadth, between the muscle fibrillæ which gives to the meat on close inspection, a speckled appearance; if such meat be eaten imperfectly cooked, the gastric juice frees the embryo of its capsule, and the trichinæ are set free in the intestines, and after 48 hours become mature. The females are considerably larger than the males, and more numerous, they are about 1-8th of an inch in length, whereas the males are

Fig. 5—Ova of *Tænia solium*.
Magnified about 400 diameters.

only about 1-20th to 1-14th of an inch long. The mature trichina live for four or five weeks. Within 7 days embryos are produced alive, the eggs being hatched in utero. One female is said to be able to produce 10,000 to 15,000 young, and these burrow through the walls of the intestine and seek seclusion in the interior of the separate muscular bundles, of striped muscle (only excepting that of the heart) where they set up a considerable amount of inflammation, and gradually become encapsuled, or else the females bore their way into the villi, and the embryos are deposited in the chyle vessels, through which they reach the voluntary muscles. A temperature of 48° C is fatal to the *Trichina spiralis* both free and in a cyst.

Fig. 6—Trichina spiralis (encysted).

In trichinosis in the human subject, the mortality varies, but is often severe. The symptoms are pain in, tenderness over, and swelling, of the muscles, which unlike rheumatism, does not affect the joints, the slightest movement of the muscles causes pain, there is fever, gastro-intestinal disturbance, dyspnœa, at the end of a week œdema in the eyelids and face, neck, or extremities, sets in. Prostration is a marked feature, and death may be caused by bronchitis, pneumonia, peritonitis, enteritis or by exhaustion.*

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* The following is from the *B.M.J.*, p. 914, 24th Sept., 1898:—"Dr. Thomas Brown, of Baltimore, has recently published some valuable researches on the pathology of this disease based on the examination of three cases. He finds a remarkable change in the blood as the result of trichi-

A thin shaving of trichinous meat may be examined by soaking for a short time in weak liquor potassæ, or acetic acid, then draining off the water, and mounting in glycerine and water and examining with a one-inch objective. The parts where the trichinæ are most likely to be found are as one would naturally suppose, those in closest proximity to the gastro-intestinal tract, such as the muscular part of the diaphragm, and abdominal and intercostal muscles. The muscles of the eye, jaw, and under surface of tongue are also places where a search should be made.

Miescher's tubes or Rainey's Capsules are small kidney-shaped bodies, from 1-300th to 1-4th of an inch long, enclosed in a tough thick cuticle, perforated by numerous pores. They are met with in cattle, swine, sheep, deer, and mice, and they have been said to cause difficulty in breathing, and in some paralytic symptoms; they have never been found in man.

The diseases which in advanced cases render the flesh unfit for food, but which in the early stages do not cause any appreciable alteration in the flesh are these :—

(*1*) Foot and Mouth disease.
(*2*) Foot-Rot. Parasitic diseases, such as :—
(*3*) Rot (caused by Fluke worm) and "Staggers" (*Coenurus cerebralis*). *Strongylus filaria* in the lungs of sheep, *Strongylus paradoxus* in the lungs of the pig, and *Strongylus micrurus* in the lungs of the calf.
(*4*) Parturient diseases.
(*5*) Any disease producing a dropsical condition of the flesh.

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nosis. The normal proportion of the eosinophilic cells to all the white cells is from about 2 to 4 per cent.; in trichinosis there is a great increase of white cells, but this leucocytosis is of a special kind. An extraordinary relative and absolute increase of eosinophiles occurs. In one severe case they rose to 68 per cent. when the symptoms were at their height. The proportion fell in all cases as the patient got better. This excess must profoundly affect nutrition if it be true, as Kanthack and Hardy believe, that, unlike other leucocytes, the eosinophile cannot act as a phagocyte. Dr. Brown fortunately traced one patient, and once more examined his blood, five months after he had been discharged with nearly 35 per cent. of eosinophiles in his blood. The man was then free from all other symptoms of trichinosis, and remained so to the end of the five months. Dr. Brown found, according to a note in the *Boston Medical and Surgical Journal*, that the eosinophiles had dropped down to 3 per cent. Hence, as Dr. Brown remarks in his original memoir, published in the May number of the *Journal of Experimental Medicine*, if further observation shows eosinophilia to be characteristic, we shall be furnished with a symptom of great diagnostic value in trichinosis, a symptom which, perhaps, may help to clear up some of the cases which are regarded as rheumatic in nature during life, the true diagnosis being revealed only years afterwards on the necropsy table."

(1) Foot and Mouth disease, or *Eczema epizootica* is a very contagious disease, affecting cattle, sheep, pigs, and according to some, horses, poultry, hares, and rabbits. It is said to be caused by a streptococcus, which resembles *Streptococcus pyogenes* but grows less rapidly on gelatine. The symptoms of the disease, are fever, salivation, evidence of pain in feeding, shown not by refusal of food, but by dropping the food from time to time as if in pain. On examination an eruption of a vesicular nature is seen on the tongue and mucous membrane of the mouth, which may extend into the throat and nostrils. If the feet also are affected, as is commonly the case, the eruption is seen around the hoofs and in the cleft. The blisters in the mouth burst and leave small ulcers, whilst those around the feet frequently dry up and form scabs. If the inflammation around the foot is acute, there may be so much ulceration as to cause the hoof to be loosened or shed. In cases where the feet are affected there is lameness. Occasionally the eruption appears on the teats in milch cows, ewes, or sows, the milk from such animals reproduces the disease along the alimentary canal. In order to prove that the infection could be conveyed by the milk of an affected animal, Hertwig drank a pint of warm milk from a cow in which the disease had affected the udder; after two days he became feverish, restless, and experienced tingling of the hands; these symptoms lasted seven days; on the ninth there was a vesicular eruption on the tongue, and on the mucous membrane of the cheek and lips, at the same time the eruption appeared on the hands and fingers, those in the mouth soon burst, leaving small ulcers, those on the hands lasted longer and were converted into scabs.

In mild cases the flesh is unaltered in appearance or condition, but if the cases have been severe, and the animals exposed to cold and wet, or to bad surroundings, then the disease may take on the nature of septicæmia, and render the flesh quite unfit. Under ordinary circumstances only parts affected are condemned. Isolation, disinfection, and under certain circumstances slaughtering are the means employed to stop the spread of the disease; recourse to slaughter is not often necessary.

(2) Foot Rot. This is a common disease of sheep, especially prevalent upon damp land, hence the popular idea, that the rot was produced by moisture. The disease has been recognised as contagious since 1805, but it would appear that exposure to the virus must be prolonged, and a damp pasture is more favourable to the spread of the disease than dry soil. The disease is frequently contracted by healthy sheep being penned up with affected ones, the discharge from the feet being freely spread about in the places where diseased

animals have stood. The incubation period is from ten to twenty days, the disease is recognised by inflammation, swelling and evidence of pain in the affected foot, which eventually leads to exfoliation of the hoof, and to the growth of a horny excresence between the digits. In the early stages when the

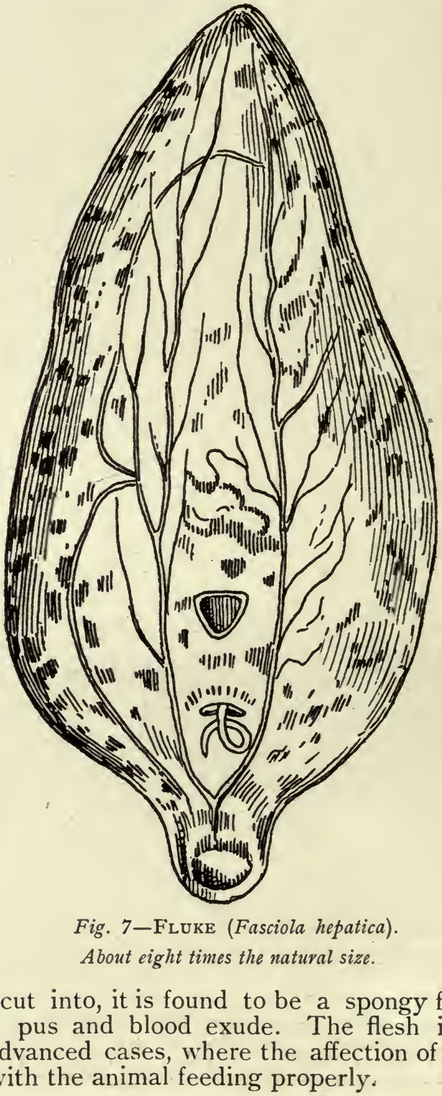

Fig. 7—Fluke (*Fasciola hepatica*).
About eight times the natural size.

swelling is cut into, it is found to be a spongy fungoid mass from which pus and blood exude. The flesh is unaffected except in advanced cases, where the affection of the feet has interfered with the animal feeding properly.

(3) The "Rot" and "Staggers" are two parasitic diseases which do not necessarily unfit the carcass for food. Rot is a disease not to be confounded with the hoof-rot; rot is especially prevalent in damp pastures, because it is due to a parasite one stage of whose existence *must* be spent in water. This disease is caused by the parasite called the fluke (from its resemblance to the fish of that name). The fluke (*Fasciola hepatica*), which is a trematode worm, is met with in the livers of sheep, and more rarely in oxen. The eggs of the fasciola develop in water into ciliated embryos, each 1-190th of an inch in length, which for a time are free and actively motile, they next lose their ciliated covering, become less active, and are probably swallowed by small water snails, and each develops still further whilst in its intermediate host into a large sac, developing new larvæ within its interior, these larvæ are provided with tails and when fully developed are known as *Cercariæ*. The cercariæ now either escape from their host and once more lead a free existence, and become attached to grass or else become encysted in their intermediate host. It is whilst free that they are swallowed by the sheep or other animal and at length become lodged in the liver, partly shed their tails, and after some weeks eventually as mature flukes, reach the bile ducts, which by their presence they may either block or burst. The sheep becomes jaundiced, the wool comes out, there may be dropsy, emaciation and consequent deterioration of the flesh so that it must be condemned; but in mild cases where the flesh is not affected, it is passed as fit for food. The livers are, of course, condemned.

"Staggers," "gid," "goggles," "sturdy," or "turnsick" are various names for a disease of a sheep generally under two years of age, the symptoms of which are a heavy wandering aimless gait, and the performance of peculiar irregular, whirling movements* and convulsions, the pupils are dilated, the conjunctiva bluish, and total blindness may follow. It usually terminates fatally from exhaustion and inanition through inability to take a proper amount of food, and is due to the presence of hydatid in the brain. The presence of the cysts in the brain often, by the increase of pressure, causes thinning and absorption of the bones of the skull. Scotch shepherds feel for the softened part of the skull, then pierce the brain with an instrument called a borer, and tap the cyst if possible, drawing it out. The hydatid is the encysted larva

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*The nature of these movements depends on the part of the brain where the hydatid is lodged. The sheep turns to the right or left according to which hemisphere of the brain is affected. The loss or co-ordination is noticed in cases where the cerebellum is the part affected.

of a species of tape-worm (*Tænia cœnurus*) and the cysts vary in size from a pea to a pigeon's egg when found in the brain, but may be much larger if found in the spinal canal. The cysticercal form of *Tænia cœnurus* like that of *Tænia echinococcus* is remarkable from the fact that one vesicle may contain a number of immature tape-worms. Each vesicle contains the heads of a number of tape-worms all attached to it by narrow stalks, which are the bodies of the tape-worms, and are usually about 1-6th of an inch in length, and the transverse diameter of the head is about 1-18th of an inch. The heads, when magnified, are each seen to consist of a rostellum, two rows of hooklets numbering about thirty (fifteen in each row) and four suckers. The mature *Tænia coenurus* infests the dog, and the larval form is found in cattle, sheep, deer, and various other animals. Since the *Tænia cœnurus* requires the dog to act as its host when mature, it is not difficult to see that those flocks which require dogs to guard them, or come in contact with dogs, are the flocks which are most likely to be affected, and many shepherds and farmers at one time thought that the brain affection was the result of the sheep being worried by the dogs, and so prevented dogs from coming in contact with the sheep, thereby checking the spread of the disease, though, at the same time, ignorant of the part played by the dogs.

Worms in the lungs are by no means uncommon in sheep, calves, and pigs, and give rise to irritation in the throat, spasmodic cough, often a considerable amount of wasting and anæmia, with great debility and dropsy; occasionally death occurs from suffocation, owing to the worms blocking the wind-pipe. Animals suffering from lung worms are often otherwise in perfect health, so that on inspecting the carcasses of animals affected by lung worms, each case is judged on its merits. *Strongylus filaria* is met with in the lungs of sheep, and also in the air passages in the form of eggs and fully developed worms. *Strongylus filaria* is a nematode worm, the female rather larger than the male, varies in size from 1 to 2½ inches in length, is of a white colour, whereas the male is yellowish. Reproduction is viviparous, but eggs are also produced. It does not appear certain how it is that the eggs become lodged in the lungs; it is probable that the mature worm is deposited on grass, is swallowed by the sheep when grazing, pierces the walls of the stomach, and so reaches the lungs. The ova are so universally distributed through the lungs, that it is possible that the eggs have entered the general circulation, and have been carried to, and lodged in the pulmonary capillaries. *Strongylus micrurus* is met with in the lungs of calves: and *Strongylus paradoxus* in those of pigs. Both varieties are capable of producing death by suffocation if present in considerable numbers in the windpipe; and they affect the general health and condition of their hosts in the manner alluded to when speaking of *Strongylus filaria*. The flesh is, therefore, in each case, judged on its merits.

(4) Parturient Diseases. Animals killed immediately before, during, or after parturition are not necessarily condemned. In cases of prolonged labour, where there is much bruising, signs of inflammation, or possibly extravasation of blood, such parts should be condemned; but other parts where there is no evidence of unsoundness, the flesh possessing all the characters of good meat, is passed as fit.

In milk-fever, if the case has been a severe one, the meat will have deteriorated to such an extent as to be unfit for food, but if not severe, and the flesh appears good, it is passed; in all these cases each one is decided upon its own merits; consequently these are the cases which call especially for the exercise of careful discrimination by municipal sanitary authorities, for instance, in a case which I saw not long ago at Portsmouth, by the kindness of the M.O.H.; the cow had died of milk fever, the flesh was pale in colour, watery, readily broke down on pressure, there was an unpleasant odour, and the Sanitary Inspector had rightly seized the whole carcass, which had been surreptitiously purchased and conveyed to the premises of a small butcher, and was intended for sale for human food.

CHAPTER II.

POULTRY.

This is divided into two kinds. The white fleshed and the dark fleshed, characterised in the one case by a remarkably small, and in the other a considerably large amount of fat in the flesh. The white-fleshed fowls contain about 4 per cent. fat, whereas the dark fleshed contain 10 times that amount. Under the term white fleshed are included chickens, turkeys, and guinea-fowls. Ducks and geese belong to the second division.

Chickens are usually carried on board men-of-war for the use of officers' messes, it is therefore advisable to be conversant with the signs of health and disease in regard to these birds. The feathers are glossy and elastic in health, the eyes are bright, nostrils free from discharges, movements active, combs and wattles firm and of a bright red colour, as the bird ages so the comb and wattles become darker in colour. The flesh should be pinkish or yellowish in colour, according to breed, firm and elastic, plump, show no signs of discolouration, have no unpleasant odour, and the breast bone should be unbroken.

The most serious diseases affecting the chicken are (1) *Tuberculosis*, (2) *Chicken cholera*, (3) *Fowl enteritis*.

(1) *Tuberculosis* is known generally as roup, and is shown by an offensive discharge from the nostrils and eyes and mouth, which has at times a diphtheritic appearance; the wattles are of a dark colour.

Fowls are very susceptible to human tuberculosis, but there is a natural tuberculosis in fowls, the bacillus of which differs somewhat from the human and bovine varieties. The identity of avian and human tuberculosis* has, in the opinion of Nocard, been established; who thinks that they are two varieties of the same species but not different species. The cultures of human tuberculosis are dry and warty, but in the avian disease, fatty, shining, and soft; the temperature at which the micro-organisms ceased to grow was different in

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* *B.M.J. Epitome*, p. 36. 27th Aug., 1898.

the two varieties. Human ceased to grow at 42° C. Avian bacilli continued to develop at 43° C. and 44° C. Fowls showed themselves refractory to inoculations of human tuberculosis, though they acquired it in the manner described below from a tuberculous poultry-keeper. To avian tuberculosis they succumbed rapidly after inoculation.

Dogs could be infected by injections of human tuberculosis which resisted the avian variety.

Very few guinea-pigs die after inoculation with the B of fowl tuberculosis, whereas if that of human or bovine tuberculosis be injected the result is invariably fatal, the average duration of the disease being 100 to 120 days after inoculation.

In the case of rabbits, these animals were susceptible to both varieties, but after infection with cultures of human tuberculosis they showed generalised tubercle, and after avian infection, death from bacillary septicaemia.

By keeping cultures of human tuberculosis in collodion for from six to eight months in the peritoneum of fowls, the bacilli acquired all the morphiological properties of avian tuberculosis.

Fowls readily spread the disease by means of contact, and possibly through the excreta. A case is recorded where a severe outbreak of tuberculosis in a poultry yard was traced to the caretaker, who was suffering from phthisis, and there was no doubt but that he infected the birds with his sputum, the grain becoming contaminated at feeding times. Other cases have been traced to birds being fed on the infected organs of tuberculous cattle. The parts generally found to be the seat of tubercle are the liver and spleen. Klein says that it is a remarkable fact that "in most instances, notwithstanding the tuberculosis going on in their spleens, the animals are very fat, when, however, the liver becomes involved to a large extent, the animal is found to become emaciated."

Moule states that in a French village where fowl-tuberculosis was prevalent, the people were in the habit of preparing a paté from livers in an early state of tuberculous disease, being under the impression that they were dealing with the true fatty disease of the liver, which is cultivated in the preparation of fatty livers for paté-de-foiè-gras.

Chicken cholera is a rapidly fatal disease which is highly contagious. It has an incubative period of from 16 to 24 hours, death occurring in from 36 to 48 hours. It is fatal to pigeons and rabbits. The symptoms are thirst, drowsiness, (drowsiness is a remarkably prominent symptom) tottering gait, refusal of food, dragging of the wings, bristling of the feathers, diarrhœa, the evacuations being fluid and of a greenish colour, and convulsions terminating in death. After death the flesh is seen to be redder than normal, and there is intense congestion of the intestines and other viscera, together with hæmorrhages; numerous short oval non-motile bacilli are met with in these cases in the blood and intestines. Pasteur suggested the eradication of rabbits in Australia, by inoculating a certain number with the microbe of this disease. A disease with very similar symptoms is duck cholera, to which chicken are insusceptible.

Fowl enteritis is an infectious and fatal disease amongst fowls, but which does not affect pigeons at all, and rabbits only to a slight extent; it is characterised by diarrhœa, but not by somnolence. It is fatal in about forty-eight hours after the diarrhœa has commenced. The intestines show no hæmorrhage, but are congested, and coated with a greyish slime, the liver is congested, the spleen enlarged, lungs unaffected. Bacilli are found in the blood, but to a less extent than in fowl cholera, and these are longer and thicker than those of fowl cholera.

Minor Ailments.

Under this term are included:—

(*1*) Catarrhal diseases.

(*2*) Errors of diet.

(*3*) Parasitic diseases.

(1) *Chip.* This is a disease to which young chicken are especially liable in wet cold weather, or in damp, insanitary fowl houses. It derives its name from the peculiar cry emitted by the birds, which sit about and cry, "chip, chip."

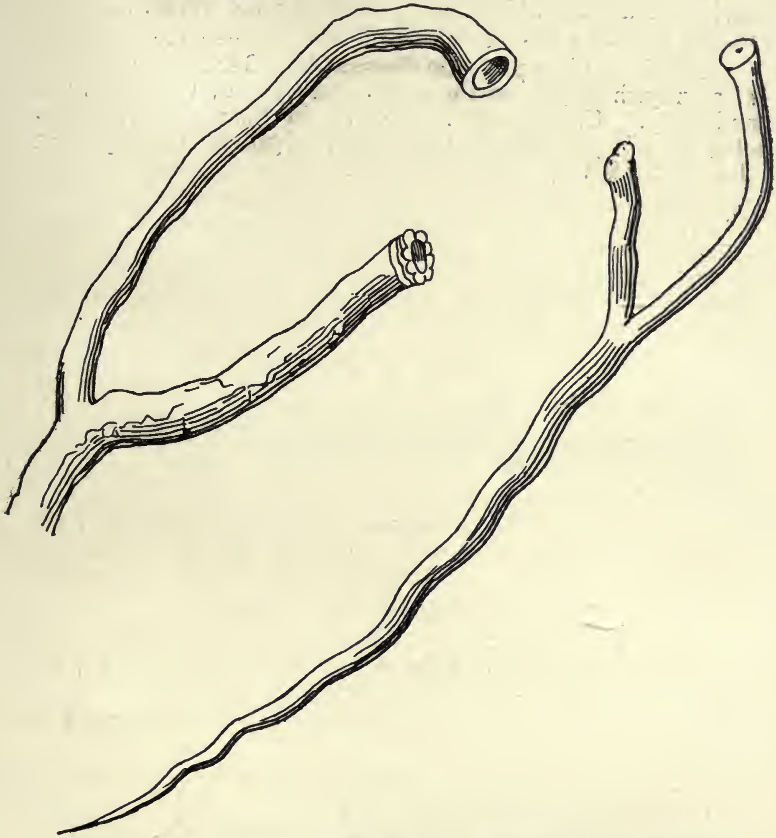
(2) *Pip* is included under this class; it is a name for a horny growth on the tip of the tongue which appears when the bird is out of sorts from some cause or other.

Scour is the term for diarrhœa, the result of errors in feeding.

Turn is an apoplectic condition met with occasionally in over-fed fowls which have been deprived of exercise.

(3) *Gapes* is an affection of the breathing, usually of young birds, in which there is much distress. The cause is the presence of a round worm in the trachea called *Sclerostoma syngamus*.

This worm was at one time considered to be a trematode, but is now known to be a round worm. It consists of a wavy cylinder, *i.e.*, the body is nearly of one breadth throughout, tapering at one end and bifid at the other. The pointed end is the tail; at the branched end, the furthermost arm is the mouth, the other consists in a sucker, by which it adheres to any part where it may be situated. More than half-a-dozen have often been found in the trachea, and here they set up a considerable amount of inflammation, and often mechanically cause suffocation and death.*



Magnified about 6 times.

Whole worm—magnified about 3½ times.

Fig. 8— Gape Worm (*Sclerostoma syngamus*).

They may sometimes be dislodged by a well oiled feather passed down the throat, and then rotated so as to sweep the

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* There is a great difference in the sexes. The male is about 1-8th of an inch long, with a body having a transverse diameter of from 1-60th to 1-50th of an inch. The female are about 5-8th of an inch long, and the body is about 1-35th of an inch in its transverse diameter.

whole of the trachea; after which the the feather and worm must be completely destroyed in order to prevent reproduction. As a rule, however, the chicken dies exhausted.

On chicken farms, as a rule, where individual attention would be impossible, various disinfectant powders are sprinkled about, which are inhaled by the birds, and the worms are then readily detached and coughed up.

Fowl-Scab is a parasitic disease characterised by patches of a greyish colour on the comb and wattles, or on the neck and body. Crookshank mentions it in his work on bacteriology as being caused by a white mycelial growth, and says that the disease is very similar to favus.

CHAPTER III.

FISH AND MOLLUSCA.

Fish, for our purpose are divided into three classes, white fleshed, red fleshed, and greasy fish.

The white fleshed possess 2·9 per cent. fat* and about 18 per cent proteids. Amongst these may be mentioned, cod, whiting, plaice, haddock, sole, flounder and turbot.

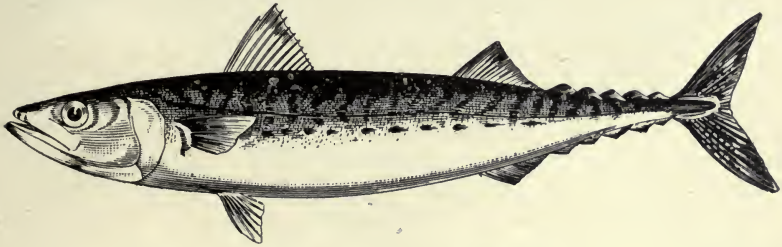

Fig. 9—MACKEREL (*Scomber scomber*).

The salmon is the typical red fleshed fish and possesses a considerable amount of fat, 12·70 per cent. fat and 21·6 per cent. proteids.

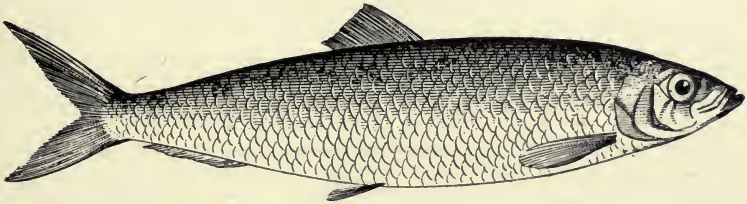

Fig. 10—HERRING (*Clupea harengus*).

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*Dr. H. Letheby on Food.

The greasy fleshed fish include such varieties as herring, mackerel, pilchards and eels, which contain from 7 per cent. to 14 per cent. fat.

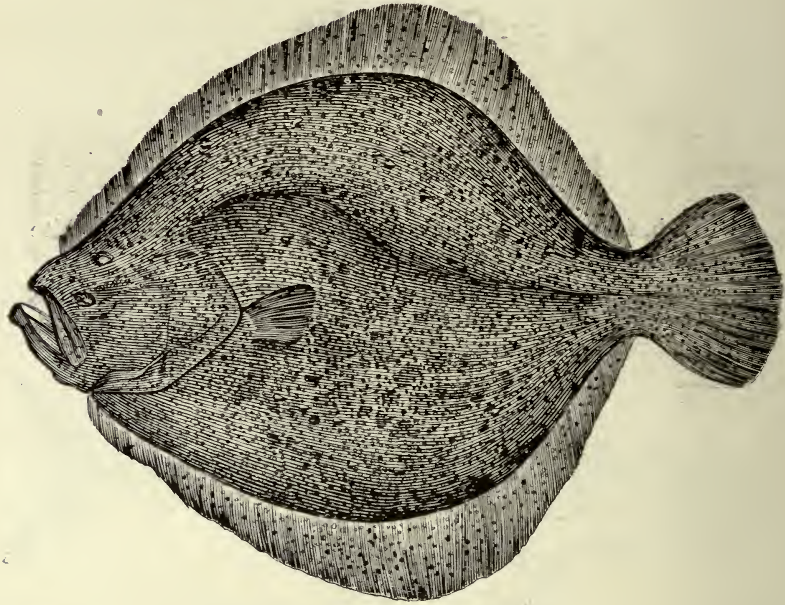

Fig. 11—Turbot (*Rhombus maximus*).

It would be superfluous to say that fish for food should be fresh, that is to say fish which has not been cured, but there are degrees of freshness, and certain fish keep well, and others badly. Surface fish such as mackerel and herring must be eaten as soon as they are caught. One often hears of cases of poisoning by mackerel some of which are undoubtedly due to the fish being eaten when out of season, but a great many are due to the fish having been kept too long, a few hours more or less often makes all the difference. They should never be

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*At Nouméa, New Caledonia, red mullet are kept alive in tanks of salt water and not taken out until sold, when they are fastened together on a string.

At Bermuda fish ponds swarming with fish are common. The fish, after being caught, are kept alive in the well of the boat and then transferred to the pond, to be used for food as required.

eaten unless cured when they have been more than 24 hours out of the water. Cod, whiting and haddock will keep a little longer, especially if rinsed with salt water and kept cool.*

Fig. 12—Plaice (*Pleuronectes platessa*).

Flat-fish or bottom-fish keep better, examples of these are plaice and turbot.

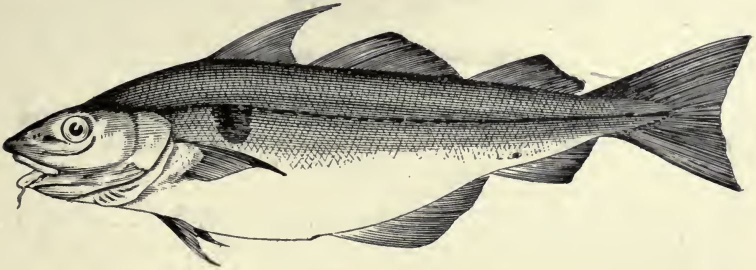

Fig. 13—Haddock (*Gadus æglefinus*)

The signs of fresh fish are as follows:—They are firm and elastic to the touch, solid and opaque, not semi-gelatinous and watery, the flesh firmly adherent to the bones, the scales and gills bright, (occasionally cases have been met with where the gills have been artificially coloured with fresh bullocks blood) eyes prominent, smell not unpleasant, no drooping of the tail if the fish be held horizontally by the head. If the fish be held firmly between the finger and thumb and pressure exerted, the flesh should not separate away from the skin, if it does, it shows that decomposition is commencing. Another valuable sign of commencing putrefaction is the readiness with which the flesh separates from the bones, leaving at the same time a mark like that left by a rusty nail in a plank after it is withdrawn. Phosphorescence is occasionally seen in the dark when decomposition is commencing, also Iridiscence or peacock feather glint is occasionally seen during the day. Fish with oily livers, if ungutted, often appear fresh on the outside long after decomposition has commenced within. Fish should always be gutted as soon as caught, and also well bled.

The Norwegians always bleed the fish as soon as they are caught by making incisions just below and behind the gills, or else above the tail, and always gut them at once.

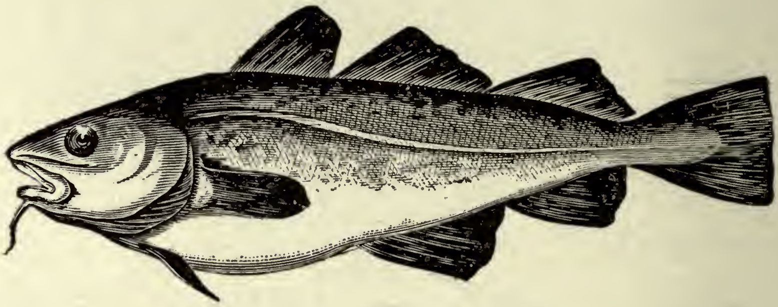

Fig. 14—Cod (*Gadus morrhua*).

Bruising in fish is just as harmful as it is with butchers' meat. Bruised fish will not keep at all, and is never fit for food unless absolutely fresh.

The practice of keeping fish on ice, which of course is unavoidable in warm weather, is very detrimental to the quality of the fish, it makes it tasteless, soft, and flabby.

Fish should be in season; it is usually at its best before spawning (during spawning it is unfit for food and is thin and flabby in appearance). A very good list of the seasons for the commoner varieties of English fish is given in *Whitaker's Almanack*, as follows—

The letter (*e*) signifies that the fish are then in their prime; the letter (*c*) signifies that the fish may be obtained, but are not at their best; the letter (*s*) signifies that it is "close-time" as fixed by statute.

NAME OF FISH.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Barbel	*e*	...	*s*	*s*	*s*	*s*	...	...	*c*	*e*	*e*	*e*
Bass	...	...	...	*e*	*e*	*e*	*e*	*e*	*c*	...	...	...
Bream	*e*	*e*	*s*	*s*	*s*	*s*	...	*c*	*e*	*e*	*e*	*e*
,, (sea)	...	...	..	...	...	*c*	*c*	*e*	*e*	*e*	*e*	*e*
Brill	*e*	*e*	*e*	*c*	...	...	*c*	*c*	*e*	*e*	*e*	*e*
Carp	*e*	*e*	*s*	*s*	*s*	*s*	...	*c*	*c*	*e*	*e*	*e*
Catfish	*c*	*e*	*e*	*e*	*e*	*e*	*c*	...	..	...	...	...
Char	*s*	*c*	*c*	*c*	*e*	*e*	*e*	*e*	*e*	*s*	*s*	*s*
Chub	*c*	*c*	*s*	*s*	*s*	*s*	*c*	*e*	*e*	*e*	*c*	*c*
Coal Fish or Saithe	*e*	*e*	*e*	*c*	*c*	...	...	..	...	*e*	*e*	*e*
Cockle	*e*	*e*	*e*	*e*	...	...	*c*	*c*	*e*	*e*	*e*	*e*
Cod	*e*	*e*	*e*	*e*	...	...	*c*	*c*	*c*	*e*	*e*	*e*
Conger	...	*c*	*c*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*c*	...
Crab	*c*	*c*	*c*	*c*	*e*	*e*	*e*	*e*	..	*c*	*c*	*c*
Crayfish (*a*)	*c*	*c*	*c*	*c*	*e*	*e*	*e*	*e*	*c*	...	..	...
Dab	*e*	*e*	*e*	*e*	*c*	...	...	...	*c*	*c*	*c*	*c*
Dace	*e*	*e*	*s*	*s*	*s*	*s*	...	*c*	*c*	*e*	*e*	*e*
Dory	*c*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*
Eel	*e*	*e*	*e*	*e*	*e*	*c*	*c*	*e*	*e*	*e*	*e*	*e*
Flounder	*c*	*e*	*e*	*e*	...	...	*e*	*e*	*e*	*e*	*c*	*c*
Grayling	*c*	*c*	*s*	*s*	*s*	*s*	*c*	*e*	*e*	*e*	*e*	*e*
Gudgeon	*c*	*c*	*s*	*s*	*s*	*s*	...	...	*c*	*e*	*e*	*e*
Gurnard (red)	*e*	*e*	*c*	...	..	...	...	*c*	*e*	*e*	*e*	*e*
,, (grey)	*c*	*e*	*e*	*e*	...	.	...	...	*e*	*e*	*e*	*e*
Haddock	*e*	*e*	*c*	*c*	...	...	*c*	*c*	*e*	*e*	*e*	*e*
Hake	*e*		..	..	*c*	*c*	*e*	*e*	*e*	*e*	*e*	*e*
Halibut	*e*	*e*	*e*	*c*	*c*	..	..	*c*	*c*	*e*	*e*	*e*
Herring	*c*	*c*	*c*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*
Lampern	*e*	*e*	*s*	*s*	*s*	*s*	...	...	*c*	*e*	*e*	*e*
Lamprey	*c*	*c*	*c*	*e*	*e*	*e*	*c*	...	...	...	..	
Ling	*e*	*e*	*e*	*e*	*c*	...	..	...	...	*c*	*e*	*e*

NAME OF FISH.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Lobster	*c*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*c*	*c*
Mackerel	...	...	*c*	*c*	*e*	*e*	*e*	*e*	*c*	*c*	*c*	...
Mullet (red)	...	...	*c*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*c*	...
,, (grey)	*c*	...	...	...	*c*	*c*	*e*	*e*	*e*	*e*	*c*	*c*
Mussel	*e*	*e*	*e*	*c*	...	...	...	*e*	*e*	*e*	*e*	*e*
Oyster (*b*)	*e*	*e*	*e*	*e*	*s*	*s*	*s*	*c*	*e*	*e*	*e*	*e*
Perch	*e*	...	*s*	*s*	*s*	*s*	..	...	*c*		*e*	*e*
Periwinkle	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*
Pike	*e*	*e*	*s*	*s*	*s*	*s*	*c*	*c*	*c*	*e*	*e*	*e*
Pilchard	...	...	...	..	...	*e*	*e*	*e*	*e*	*e*	*c*	*c*
Plaice	*e*	*e*	*e*	*e*	*c*	...	*c*	*c*	*c*	*e*	*e*	*e*
Pollack	*e*	*e*	*c*	...	...	...	*c*	*c*	*e*	*e*	*e*	*e*
Prawn	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	...	...
Salmon & Sea Trout (*c*)	*s*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*s*	*s*	*s*	*s*
Shad	...	...	...	*e*	*e*	*c*	*c*	...	...	...	.	...
Shrimp (*d*)	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*
Skate	*e*	*e*	*e*	*e*	...	...	*c*	*c*	*c*	*e*	*e*	*e*
Smelt or Sparling	*e*	*e*	*e*	*e*	*c*	...	...	...	*c*	*c*	*e*	*e*
Sole	*e*	*e*	*c*	*c*	*c*	*e*	*e*	*e*	*e*	*e*	*e*	*e*
Sprat	*e*	*e*	*e*	...	...	...	...	...	...	..	*c*	*e*
Sturgeon	*e*	*e*	*e*	...	...	*c*	*c*	*c*	*e*	*e*	*e*	*e*
Tench	*e*	*e*	*s*	*s*	*s*	*s*	...		*c*	*e*	*e*	*e*
Thornback	*c*	*c*	*c*	*c*	...	...	..	*c*	*c*	*e*	*e*	*e*
Torsk or Tusk	*e*	*e*	*c*	...	.	...	..	*c*	*e*	*e*	*e*	*e*
Trout	*s*	*c*	*c*	*e*	*e*	*e*	*e*	*c*	*c*	*s*	*s*	*s*
Turbot	*e*	*e*	*e*	*e*	*c*	...	*c*	*c*	*c*	*e*	*e*	*e*
Whelk	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*	*e*
Whitebait	...	*c*	*e*	*e*	*e*	*e*	*e*	*e*	*c*	...	..	...
Whiting	*e*	*e*	*e*	*c*	*c*	..	...	*c*	*e*	*e*	*e*	*e*
Wrasse	...	...	...	..	*e*	*e*	*e*	*c*	*c*	...	...	...

(*a*) This is for sea crayfish. River crayfish can be obtained in the spring, summer, and autumn. It is a moot point whether it is legal to take fresh-water crayfish from March to June.

(*b*) Foreign oysters can be sold in the close season, and are to be had almost all through the year, even though they have been laid down in English beds for storage.

(*c*) In the close season salmon from Holland and also from certain British rivers where net fishing is permitted later in the year than usual, are largely sold.

(*d*) For the first six months the bulk of our London supply of shrimps comes from Holland, but Dutch shrimps are far inferior to the English, which are plentiful from July to December.

The symptoms of fish poisoning are those of acute gastro-intestinal irritation as evidenced by vomiting and violent diarrhœa, or else prostration very intense in character and death by syncope or convulsions.

In regard to poisonous fish, sailors have a very good rule, and that is, fish with scales are usually wholesome, those without are not.

The livers of otherwise wholesome fish have been known to give rise, when eaten, to severe gastro-intestinal disturbance, as shown by vomiting and diarrhœa, followed shortly by a red-rash, and later on by desquamation.

Mussels sometimes give rise to very severe symptoms, such as indigestion, nausea, and vomiting, diarrhœa, feeble pulse, and great prostration, numbness of the limbs, urticaria, and occasionally swelling of the tongue and fauces. It was recently found that non-poisonous mussels placed in the water of Wilhelmshaven soon became poisonous, and that if transferred to the open sea, soon became harmless again.* Further, it was found that after giving water from the harbour after filtration to the mussels they became harmless, and certain low forms of life were found in the water of the harbour which were not found in the non-poisonous mussels, nor in the water from the open sea. A chemical poison, called mytilotoxin, of the nature of an alkaloid and also very virulent bacilli, were found in the poisonous mussels. Mytilotoxin is said to act like curara in paralysing motor nerves, which is quite distinct from the poison which sets up gastritis and enteritis.

Cases of Enteric fever have, in numerous well authenticated cases, been traced to mussels and oysters collected from water contaminated by sewage, which had become infected by the bacillus of typhoid fever, where the only circumstance common to the persons suffering from typhoid fever was the fact that they had partaken of the molluscs from an infected source. As a typical example we cannot do better than quote the outbreak of Typhoid fever at Wesleyan University, Middletown, Connecticut, U.S.A., given in the Appendix No. 3, to the report on "Oyster culture in relation to disease," by Drs. Bulstrode and Klein. The case at Wesleyan University was recorded by Dr. H. W. Conn. The students had some initiation suppers on 12th October; twenty-five cases of sickness, twenty-three of which were undoubtedly cases of typhoid fever followed as a result of these suppers, between 20th October and 9th November—which agrees well with the supposed incubation period of from eight to twenty-eight days—of these twenty-three cases thirteen were severe and four fatal. These students all ate oysters "on the half shell," *i.e.*, uncooked, and this was the only circumstance in common. Other people attending these suppers had eaten oysters, but these were mostly cooked. On tracing the oysters to their source, it was found that they were all from Long Island Sound, and before reaching the retailer, they had been removed to the mouth of a fresh water stream for a few days to "fatten"; between 250 and 300 feet above the place where they were left to "fatten" was the outlet of a private sewer which had been receiving the excreta of persons suffering from typhoid fever.

Eels and *Osphromenus olfax* (Mauritian gourami) have been known to acquire poisonous properties by being kept in foul ditches or tanks.

Many fish are unwholesome at the breeding season, and some French naval medical officers, who have had much experience in tropical waters, hold that many of the so-called poisonous fishes are only poisonous at that season. Many

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*24th Annual Report, Local Government Board, 1894-95.

tropical fish owe their poisonous qualities to the fact that they feed on poisonous Medusæ and corals.

In mentioning fish, the flesh of which is either always or at times poisonous, no allusion has been purposely made to those fish which are provided with poison organs intended for defensive purposes.

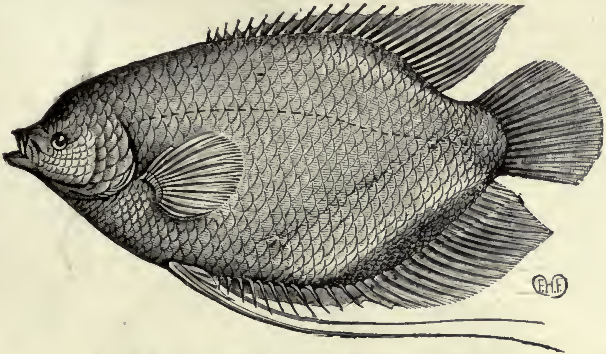

Fig. 15—GOURAMI (*Osphromenus olfax.*)

Table of fish, certain species of which are known to possess poisonous properties *(a)* inherent; *(b)* dependent on nature of food; or *(c)* due to seasonal changes.

Acanthopterygii or spiny-rayed fishes—Including *Sparidæ* (Sea-Breams); *Squamipinnes* (Coral fishes): *Sphyrænidæ* (Barracudas); *Scombridæ* (Mackerels); *Carangidæ* (Horse-Mackerels); *Acronuridæ* (Surgeons); and *Atherinidæ*.

Pharyngognathi—Including *Labridæ* (Wrasses).

Physastomi—Including *Siluridæ* (cat-fishes); *Clupeidæ* (Herrings).

Plectognathi—Including *Sclerodermi*, *e.g.*, *Balistes* and *Ostracion*; Gymnodontes (*Diodon*, *Triodon*, *Tetrodon*).

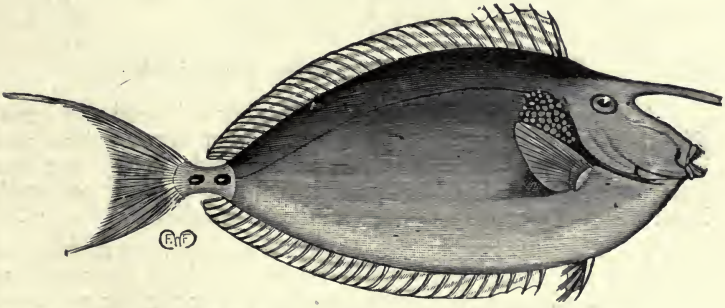

Fig. 16—*Naseus unicornis.* From the Indo-Pacific Ocean.

Naseus unicornis belongs to the family of *Acronuridæ* or Sea-Surgeons, which are especially met with in the neighbourhood of coral-reefs, since they feed on the corals or vegetable matter found near the coral, they are liable to possess poisonous properties.

Fig. 17—Heniochus macrolepidotus. Indian Ocean.

Heniochus macrolepidotus is a highly coloured and beautiful member of the genus *Squamipinnes* or coral fishes, and is mentioned in order that it may be avoided. They are like other members of the family, carnivorous, feeding on small invertebrates met with in the vicinity of coral-reefs.

The *Pagelus erythrinus* (Spanish bream), is a member of the genus *Sparidæ* (sea-bream family), and off the shores of New Caledonia and New Hebrides the fish is rightly regarded with suspicion, as at certain times there are numberless poisonous medusæ off these coasts, from which they possibly acquire their poisonous properties. The Spanish navigator Quiros, who discovered the New Hebrides, nearly died after eating this fish, and in an account of Cook's Voyages allusion is made to symptoms of poisoning which followed the eating of this fish off the coast of Mallicolo (New Hebrides).

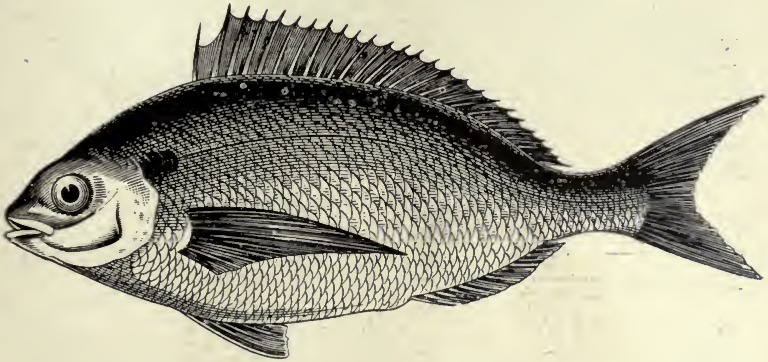

Fig. 18—BREAM (*Pagellus centrodontus*).

Lethrinus mambo also belongs to the family of *Sparidæ* or sea-breams, and according to Père Montrouzier (an authority on the natural history of New Caledonia), is very poisonous when full grown, but may be eaten with impunity when young. It is met with in the tropical parts of the Pacific. Mambo is the native name for this fish in the northern part of New Caledonia.

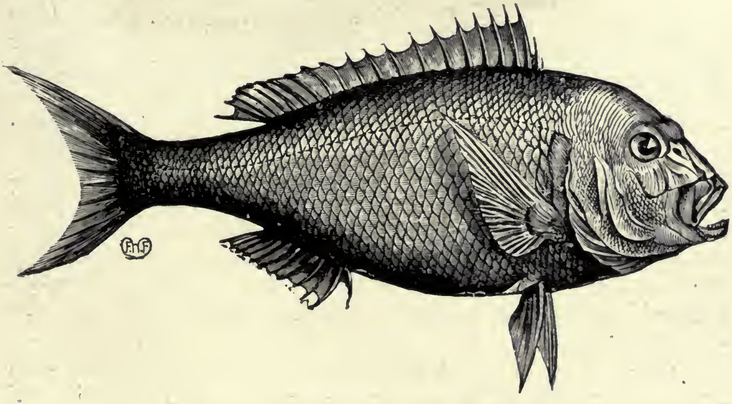

Fig. 19—THE SNAPPER (*Pagrus unicolor*).

The "Snapper," belonging to the *Sparidæ* or family of Sea-Breams, is much prized in Australia and New Zealand on account of the excellency of its flesh. "It attains to a length of more than 3 feet and to a weight exceeding 20 pounds." (Flower). The illustration of Snapper, like that of the Bream, Herring, Cod, &c., is given in order to illustrate types of fish, and so afford help in identifying various species.

Sphyraena barracuda, known in the service as "Barracudas," when met with in the West Indies are generally poisonous, through having fed on small poisonous fish. They are long fish, sometimes as long as eight feet, and forty lbs. in weight. Extremely voracious, these fish are not necessarily poisonous, but only at certain seasons or when they have been feeding on poisonous material.

Caranx fallax, or Horse mackerel, of which there are many species in the tropics, is wholesome when young, but poisonous when old. They are frequently met with in tropical Australian waters.

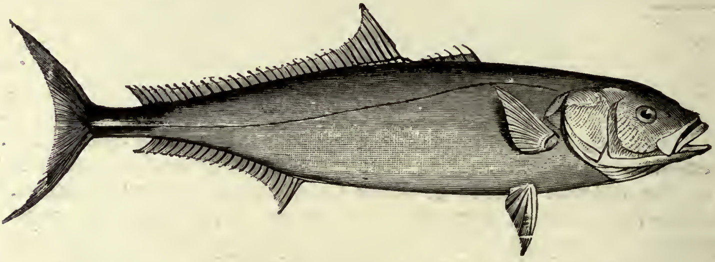

Fig. 20—YELLOW-TAIL (*Seriola lalandii*). From S. Australia.

The "Yellow Tails," which belong to the order *Carangidæ* or Horse-mackerels, of which an illustration is given in order to show the appearance of the horse-mackerel family, are much esteemed as food, and are met with in temperate and tropical seas; they sometimes attain a length of from 4-5 feet.

Tetragonurus belongs to a genus partly resembling the mackerels, partly the mullets. It is found in the Mediterranean, and is recognised by the body being rather elongated and covered with strongly keeled and striated scales. There are two projecting keels or ridges on each side of the caudal fin. It is from twelve to eighteen inches in length when full grown; the flesh of Tetragonurus is generally believed to be poisonous.

Scarus of various species, are beautifully coloured fish, some small, others weighing as much as fifty pounds; they belong to the family *Labridæ* or Wrasse, "Rock-fish," many of which class are known by their thick lips, in certain cases internally folded so as to appear double. One variety of Wrasse, known as the *Scarus cretensis*, was much valued by the ancients for the exquisite flavour of its flesh, yet if it had eaten certain food, produced diarrhœa. This fish was so much prized by the Romans that in the reign of Claudius, Elipentius Optatus, the Roman Admiral, sailed to Greece in order to obtain the fish and distribute them through the Italian seas. The tropical varieties of *Scarus*, known as parrot-fishes, on account of the brilliancy of their colours, are considered poisonous on account of the poisonous nature of their food, which are chiefly derived from coral.

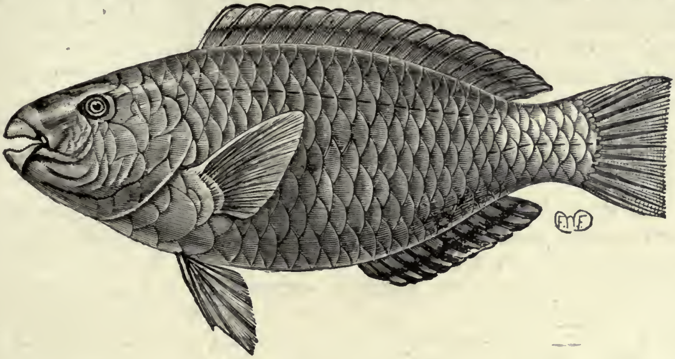

Fig. 21 --WRASSE (*Pseudoscarns troschelii*). From the Indian Ocean.

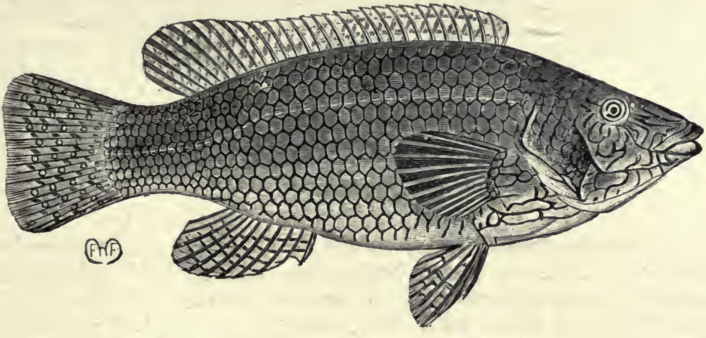

Fig. 22—WRASSE (*Labrus maculatus*).

The *Siluridæ*, or cat-fishes, are for the most part fresh-water fish, met with in all temperate or tropical regions. They have smooth skins, devoid of scales. A few varieties of cat-fish enter the sea, and keep near the coast, and it is only these which have the reputation of being unwholesome, the fresh-water varieties being good for food.

Günther in his work on fishes says, "frequently the poisonous fishes are found eatable if the head and intestines be removed immediately after capture." Günther enumerates many tropical fish which are poisonous, amongst these are several belonging to the herring family, *e.g.*, *Clupea thryssa, Clupea loniceps*, *Clupea perforata,* and *Clupea venenosa. Clupea thryssa* (sardine doré) is a common West Indian fish distinguished by having the last dorsal ray prolonged into a filament.

Clupea thryssa is extremely poisonous, and people have been known to die quite suddenly with the fish in their mouths unswallowed. A species of Clupea which the French described as a poisonous sardine, occasioned the death of five men belonging to the French corvette *Catinat,* whilst they were lying at the anchorage of Balade (New Caledonia), in the year 1856. *Clupea loniceps* (the oil sardine of the Malabar coast), *Clupea perforata* (of the Straits of Malacca), and *Clupea venenosa* (of the Seychelles), are all known to have given rise to severe choleraic symptoms. *Clupea humeralis,* a West Indian herring, after feeding on Physalia has been known, Dr. Day says, to occasion death in a few minutes.

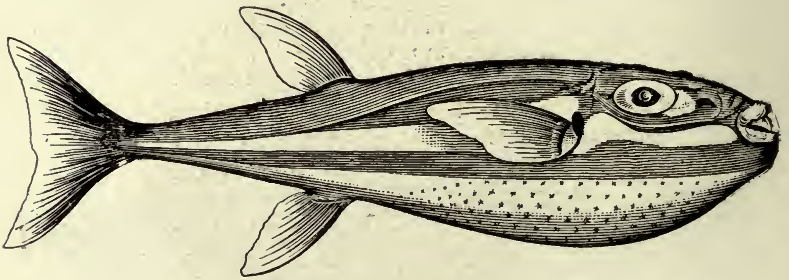

Fig. 23—Tetrodon sceleratus.

Tetrodon and *Diodon*, known as "Globe-fishes," have the power of inflating their bodies by filling with air their distensible œsophagus ; when the skin is thus stretched they roll over and float with their belly uppermost, and spines protruding: this has given rise to their being known as sea-porcupines, or sea-hedgehogs. The peculiar formation of the jaws of these fish, in which the bones of both jaws are confluent so as to form a beak with a sharp edge, should be noted. It was *Tetrodon sceleratus* which, according to Forster, poisoned some of Captain Cook's men whilst in the

New Hebrides. Letheby, quoting from Sir John Richardson, an account of a case of poisoning by a Tetrodon which occurred in Simon's Bay, Cape of Good Hope, in September, 1845, says, "the case was this: the boatswain's mate and purser's steward on board a Dutch man-of-war, after being warned of the poisonous nature of this fish, cooked and ate a piece of the liver directly after their twelve o'clock dinner. The boatswain's mate ten minutes later was so ill that he could not stand; his face was flushed, his eyes glistened, his lips were swollen and rather blue, his forehead was covered with a cold perspiration. He was, however, quite conscious, and complained of pain and constriction of the throat, and he had a desire to vomit. In a few minutes he became paralysed, his eyes were fixed, his breathing was laborious, his face was pale though his lips were livid, and in seventeen minutes he was dead." The other man died in twenty minutes with the same symptoms. The whole fish is said to have been only six or eight inches in length, and they could not have eaten more than half-an-ounce of liver between them.

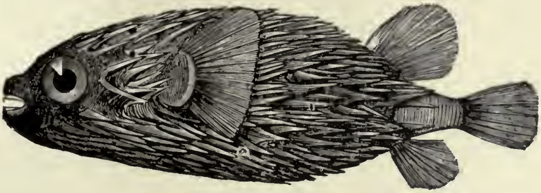

Fig. 24—Globe-Fish (*Diodon maculatus*). From the Indian Ocean.

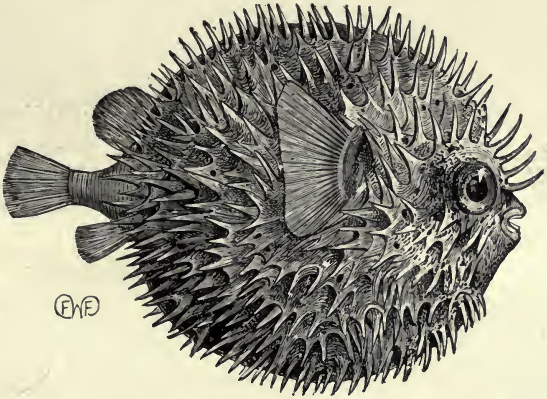

Fig. 25—Globe-Fish (*Diodon maculatus*). From the Indian Ocean. *Inflated.*

Balistes or "file-fishes" belong to the family *Sclerodermi* (fishes with hard or granulated skins), both jaws are armed with eight strong incisor-like teeth, by which they are enabled to break off pieces of small corals upon which they feed; seaweed and molluscs are also favourite foods. The dorsal fin has three rays of which the first is very strong and roughened in front like a file (hence the name file-fish), it cannot be depressed unless the second spine has been previously depressed; this second spine has been compared to a trigger which has given rise to the term trigger-fish.

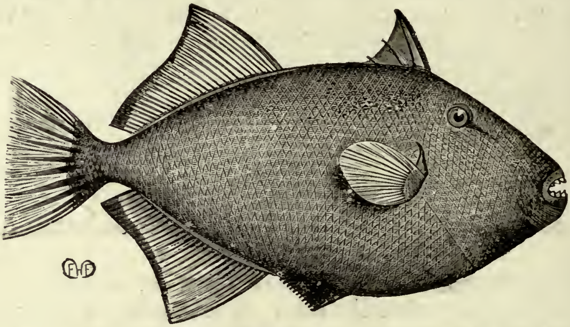

Fig. 26—File-Fish (*Balistes vidua*). From Indian Ocean.

Ostracion or trunk-fish, universally recognised as poisonous, is remarkable for having the head and body armour-plated, by plates of bones, as it were, soldered together, the fins, tail, mouth, and a small slit-like opening, bordered with a skinny edge which serves as a gill-opening, are the only unprotected parts. All these movable parts pass through openings in the armoured coat. These fish are met with in Indian and American waters.

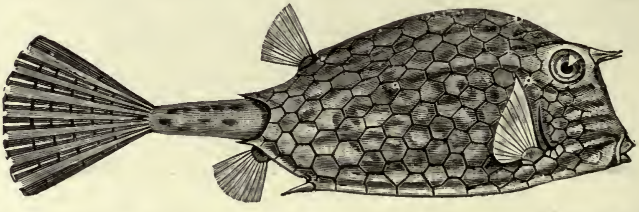

Fig. 27—Coffer-Fish (*Ostracion quadricornis*). From the West Indies.

Thynnus. Varieties of this fish are met with in tropical and sub-tropical seas; they are said by Günther to be poisonous at times. The Bonito, or striped Tunny, (*Thynnus pelamys*) is a well-known variety, and an extract from Bennett's "Whaling Voyage," vol. II., page 278, quoted by Günther, says that "this fish is a very voracious and miscellaneous feeder," flying fish, calmars, and small shoal fish are their most natural food, though they do not refuse the animal offal from a ship. Amongst the other food found in their maw we have found small ostracions, file-fish, sucking fish, janthina shells, and pelagic crabs; in one instance a small bonita, and in a second a dolphin eight inches long, and a paper-nautilus shell containing its sepia tenant."

A variety of *Zeus*, *Zeus Gallus,* or the Indian Dory, closely allied to the common "John Dory" is said to occasionally have poisonous effects when eaten. It is a native of the American and Indian seas. "John Dory," the English name for *Zeus Faber*, is said to be a corruption of the Gascon word *Jau*, meaning a cock, and Dorée, gilt. John Dory shares with the haddock the honour of having been the fish out of the mouth of which St. Peter took the coin.

The natives of New Caledonia are in the habit of treating cases of fish poisoning with the following remedy: a piece of a form of grass called "Job's tears" (*Coix lachryma*) is crushed against a stone in order to facilitate the flowing of the juice, then it is steeped in sea-water and chewed, the expressed liquid is swallowed; any value the remedy may possess is thought by some to be attributable to the sea-water, although the *Coix lachryma* undoubtedly possesses diuretic properties, just as are possessed by a decoction of couch grass.

Fish are very liable to contain parasites in their flesh which are capable of becoming parasites of human subjects; but fortunately the process of cooking, if conducted thoroughly, suffices to render such flesh harmless; parasites such as cysticerci and others infesting flesh perish invariably if exposed to a temperature of 50° C. (122°F.) for even five minutes. *Bothriocephalus latus*, belonging to the group called *Cestoda* or tape-worms, is the only parasitic worm which we know with certainty has been conveyed to man by fish. It attains to the length of twenty-four to twenty-seven feet, differs from *Tænia solium* and *Tænia mediocanellata* in having an ovoid head; it has two suckers or longitudinal grooves, and no hooklets. The segments commence about three inches from the head, and number from 3,000 to 4,000. The segments nearest to the head are square, but those further removed from the head are broader than they are long. The eggs are oval in shape and open by a lid at one end. They are longer than those of *Tænia solium* or *Tænia mediocanellata*. From the ova, after immersion in water from four to eight weeks, embryos are developed, each possessing six hooks at the anterior extremity and a ciliated mantle; these embroys swim about in a rotatory manner in fresh water, for from four to six days, after which the ciliated mantle bursts and allows a six hooked non-ciliated embryo to be set free, then if swallowed by the pike or perch, or other fish which acts as an intermediary host, they bore their way into the muscles and become encysted. It is in the cysticercal form that they reach the human subject. *Bothriocephalus latus* is said to be common in Russia, Sweden, Norway, Lapland, Finland, Poland, and in West Switzerland, especially on the shores of Lake Geneva.

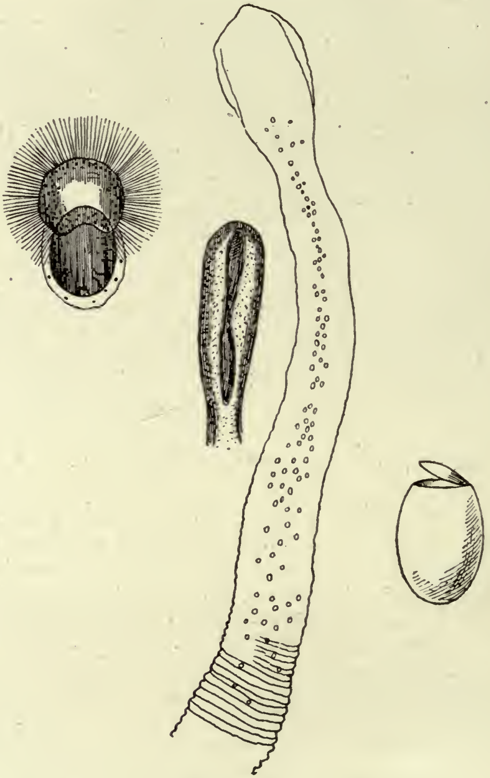

Fig. 28—Bothriocephalus latus—after Leuckart.
About ten times natural size. Ovum magnified about 161 diameters.

Eustrongylus gigas is the largest nematode worm known to infest the human subject, *it is said to be* transmitted from fish to man, but this is by no means certain. The male is from ten inches to a foot in length, and a quarter-of-an inch in breadth. The female is said (Cobbold) to attain a length of over three feet and a transverse diameter of half-an-inch. The body is cylindrical, and more or less deeply tinged with redness.

Tinned Fish.

The canteens on board men-of-war usually lay in supplies of dried fish and tinned fish, including herrings, bloaters, sardines, and salmon. Tinned fish should be consumed immediately after the tin has been opened, as degenerative changes, accompanied by the formation of poisonous ptomaïnes, are liable to occur, especially under the influence of heat. Anything remaining after the tin has been open for twelve hours should be destroyed. "It would appear," says Dr. Coppinger, R.N., "that such changes are more apt to occur in fish which have been preserved *fresh*, than in those preserved by means of salt or oil." In one of his lectures the same author says, "several cases of poisoning occurred in H.M.S. *Crocodile*, a few years ago, from the use of tinned fresh herrings, which had been lying open for forty-eight hours in a hot climate before consumption. One of these cases proved rapidly fatal." Numerous cases of poisoning by tinned fish and other provisions have been recorded in the medical journals from time to time. The symptoms usually appear a few hours (between two and three hours) after the fish has been eaten, and consist of marked collapse, frequent vomiting, diarrhœa, with pea-green bilious stools, elevation of temperature (103° to 104°F), rapid small pulse, often delirium, restlessness, and intense prostration. If the patient does not succumb, recovery will probably in severe cases not be complete until after seven or eight days havs elapsed. The nature of ptomaïnes is indicated by the following, which have been isolated from putrefying fish—

Colloidine	$C_8 H_{11} N$;	Hydro-colloidine	$C_8 H_{13} N$;
Neuridine	$C_5 H_{14} N_2$;	Muscarine	$C_5 H_{13} N O_2$;
Gadinine	$C_7 H_{16} N O_2$;	Parvoline	$C_9 H_{13} N$;

The composition of these bodies is as stated by Dr. Luff in Dictionary of Medicine.

APPENDIX.

THE tuberculin test for tuberculosis depends upon the fact that when even the smallest tuberculous lesions are present in cattle, one is able to obtain the characteristic reaction with the injection of a dose of tuberculin of from 0·3 to 0·4 gram. *i.e.*, 3 to 4 cc of 1 in 10 solution of tuberculin, prepared by dissolving 1 cc of crude tuberculin in 9 cc of 0·5 per cent. aqueous solution of phenol. This solution of dilute tuberculin must be used freshly prepared, as it will not keep well. The animal to be tested should be put to rest and the temperature in the rectum taken the day before, and again on the day of the injection. The solution of tuberculin is injected (taking the ordinary aseptic precautions) into the loose cellular tissue at the junction of the neck and shoulder. The temperature must be taken twelve hours after the injection, and twice again between the twelfth and twenty-fourth hour following the inoculation. Any animal which shows a rise of temperature amounting to 1·4°C must be be considered tuberculous. An animal which shows a slight elevation of temperature amounting to between 0·5 and 0·8°C is considered healthy, but one which shows a rise of temperature amounting to between 0·8 and 1·4°C must be regarded as suspicious, and subjected to another injection after the lapse of one month.

The method of preparing tuberculin at the Pasteur Institute, given by Besson* in his work on Bacteriology and Serotherapy, p. 443, is as follows—" A culture of avian tuberculosis is grown in glycerinated broth in a bacteriological flask. Avian tuberculosis is used in preference to the human variety because it developes more rapidly. The culture must develope a thin veil-like pellicle ; this veil-like pellicle appears from the fifteenth to the twentieth day, when grown at 37°C ; the culture is complete at the thirty-second to the thirty-fifth day. The whole of the culture is sterilized at 100°C, then concentrated to one-tenth over a water bath ; the liquid thus obtained is filtered through paper, and constitutes the crude tuberculin (*tuberculine brute*). This tuberculin is a brownish liquid of sirupy consistence, possessing a slight odour of characteristic sweetness."

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*Technique Microbiologique et Sérothérapique par Le Dr. Albert Besson. Paris—Baillière et Fils, 1898.

Besson gives the detail for purifying crude tuberculin by precipitation and drying, but the methods of purification by precipitation are expensive, and entail a loss of nine-tenths of the tuberculin.

Crude tuberculin injected into healthy animals produces no symptoms beyond a slight rise of temperature. A guinea pig can bear 2 cc without any inconvenience; a rabbit can bear very well 5 cc, it shows only a slight amount of fever and a transitory loss of flesh, and quickly recovers; Dogs and cattle do not re-act to 10 cc. Man is much more susceptible than even a guinea-pig, 0·25 cc producing in man severe indisposition—temperature rises to 102·2°F (39°C), there are shiverings, diarrhœa, and vomiting. Even ·01 cc of tuberculin can produce in man a slight rise of temperature. Man is 1000 to 1500 times more susceptible to tuberculin than the guinea-pig.

With tuberculous animals the inoculation of minute doses of tuberculin produces so intense a reaction, that it is liable to bring about a rapid death.

Half a cc of properly prepared tuberculin is rapidly fatal to a guinea-pig inoculated five or six weeks previously with tuberculosis.

3 to 4 cc of dilute tuberculin is, as stated above, the dose for diagnostic purposes. Stronger doses are liable to cause death if the animal be tuberculous, whilst, as we have already said, a healthy bovine animal shows no reaction with 10 cc of the crude tuberculin, which is ten times stronger than the dilute. These facts should point to the extreme value of tuberculin as a means of diagnosing tuberculosis in cattle, and the extent to which it has already been applied in Denmark and other countries, is shown in the statistics given on page 26.

INDEX.

PART II.

WATER, AIR, MILK, FOOD-STUFFS, WINES, ETC.

PART II.

CHAPTER IV.

WATER EXAMINATION.

In collecting a sample of water, care must be taken that the vessels employed are themselves irreproachable, the bottles should first be well rinsed with dilute hydrochloric acid, then with the purest water available, and finally rinsed and filled with the water to be examined. Not less than a Winchester quart bottle should be taken for examination, and if a full analysis is required, two Winchester quarts should be taken; the bottles must be closed with well-fitting glass stoppers, and the stoppers capped with pieces of India-rubber cloth, parchment paper, or any similar material available, no luting of any kind such as linseed meal or sawdust should be employed.

The bottles should be clearly labelled with the source and date of collection of the water, and a form stating the nature of the source of water, whether from a spring, well, etc., should accompany the sample, together with certain details, thus:—if from a well, the depth, nature of strata through which it passes, and a concise account of the nature of the collecting surface, whether there is any protection against surface washings, whether there are any likely sources of contamination such as cesspools, defective drains, middens, etc. If from a water-supply such as is met with in towns, it should state whether the supply is constant or intermittent, whether the health of the people using the water has been good; if there have been any cases of recent sickness, the nature of the illness to be stated. And lastly it should state what is the nature of the storage, if there be any, and what are the reasons for the analysis.

On receiving a sample of water, if it be possible to make a bacteriological examination, this should be done at once, and the chemical examination of the water begun with as little delay as possible. The examination, apart from the bacteriological one, is divided into three parts:—

(*I.*) Physical characters.
(*II.*) Chemical examination.
  (*a*) Qualitative.
  (*b*) Quantitative.
(*III.*) Microscopical examination of the sediment.

I. PHYSICAL CHARACTERS.

(*1*) *Colour.* In good water when a column of 18 inches is viewed from above on a white ground a certain colour is generally noticeable, this should be of a bluish grey or greenish tint. If it is brown this will probably be due either to (*a*) iron, (*b*) peat, or (*c*) sewage.

(*a*) If due to iron, the iron will be tasted, as little as 0·2 grain of iron per gallon can be distinctly tasted and the qualitative tests for iron will reveal its presence.

(*b*) If due to peat the taste will be peculiar, there will be a peaty smell on warming, the reaction will probably be slightly acid, there will be a considerable amount of oxidisable matter, and a microscopic examination of the sediment will probably show peaty vegetable matter.

(*c*) If due to sewage a disagreeable smell will be noticeable on warming, and the water will show evidence of animal organic contamination in the subsequent tests.

(*2*) *Clearness.* This is best judged by seeing to what depth printed matter can be read distinctly. Turbidity may be noticeable, if this is due to finely divided clay which is suspended this will not settle down for a long time, but if due to coarser impurities these will subside after about twenty-four hours or so, and the nature of the sediment can be determined by collecting it in one of the ways noted further on.

(*3*) *Lustre.* This term describes the amount of aëration in the water, and may be described as Brilliant, Vitreous, or Dull, according to whether the water is well or badly aërated.

(*4*) *Taste.* This should be agreeable and possess the indescribable quality known as palatibility; as a rule this is due to aëration; good waters are always palatable, but the converse by no means always holds good, since some of the pleasantest tasting waters have been known to deal death to all who drink thereof.

A water has a saline taste when the total solids are present to the extent of about 100 parts per 100,000, or less if calcium sulphate be present to any extent. When the salts are chiefly composed of sodium chloride, and present to the extent of 120 parts per 100,000, the water is distinctly brackish. Sodium chloride may be present to the extent of 75 grains per gallon (107 parts per 100,000) before it can be distinctly tasted Iron is readily tasted when about 0·35 parts per 100,000 of ferric carbonate is present. Rain water is generally mawkish in taste, and distilled water free from dissolved gases tastes flat.

(*5*) *Smell.* Occasionally a water possesses a distinct odour, such as the Harrogate and Strathpeffer waters do (H_2S), but as a rule even in polluted waters no smell is noticeable until it has been warmed, this should be done by taking 200 cc of the water in a clean stoppered bottle, plunging it in a basin of water having a temperature of 60°C. (140°F.), and after a few minutes removing the stopper and smelling; a good water should show no smell on being subjected to the test of warming.

(*6*) *Sediment.* This is collected by shaking the sample and pouring some of it into a sediment glass, which should then be covered and set aside in a cool, dark cupboard; at the end of a few hours the sediment may be removed with a pipette and examined microscopically with a low power, (1 inch or $\frac{1}{4}$ inch) objective. The nature of the sediment should be carefully noted; this may be Mineral, Vegetable, or Animal. Mineral matter; Sand particles show rounded outlines and are unaffected by hydrochloric acid; likewise clay and marl will be unaffected by this acid. If the sediment consists of iron it will be present as hydrated oxide $Fe(OH)_6$, seen as reddish brown amorphous masses, soluble in hydrochloric acid and giving a blue colour with potassium ferrocyanide. Chalk particles dissolve with effervescence on the addition of a drop of the acid, and prior to this show, as a rule, a rounded outline.

Vegetable matters include débris, such as pieces of wood, leaves, living or dead algæ, desmids, diatoms, linen and cotton fibres, spiral vegetable cells, potato or other starch cells, macerated paper, &c. The last few items are particularly important as they denote contamination by house refuse; some of these will be described in detail later on, *vide* p. 102.

Animal matters. Animalcules abound in water containing decaying animal or vegetable matter, and in water which has been allowed to stagnate; although many of them are harmless, yet they show that there must be food to support them. Some of them are readily visible with the unaided eye, such as Cyclops quadricornis *(fig. 29)*, or Daphnia pulex, met with in pond water, many varieties are microscopic, and are always found in pond water or water allowed to stagnate and exposed to air, such as rainwater in casks; amongst these are the Protozoa which are sub-divided into (*a*) Rhizopoda, of which the amœba is a common example; the amœba is an animal devoid of integument, a shapeless mass of protoplasm throwing out processes into which the rest of the body is dragged. (*b*) Infusoria, which are more or less of the nature of simple cells, supplied with vibratile cilia; examples:—Paramecium, Polytoma, Monas, Euglena, Stenor. (*Fig 30*).

Coelenterata, in which the lining membrane of the stomach is continuous with that of the body cavity; example:—Hydra vulgaris. (*Fig 29*).

Annuloida includes the class scolecida (worms) and such genera as auguillulæ and rotifer, the rotifers are met with in stagnant waters which contain decomposing organic matter, and anguillulæ are never found in good water.

Annulosa includes a large number of animals met with in stagnant water, and animals grouped under this head are characterised by bodies distinctly ringed and jointed, it is divided into two divisions:—

(*a*) The Anarthropoda, those without articulated limbs.

(*b*) The Arthropoda, or those which have articulated limbs.

Leeches come under group (*a*), whilst (*b*) includes the Crustacea with a variable number of limbs, such as cyclops quadricornis, the Arachnida or spiders which have eight limbs, and Insecta with six.

Insecta may be met with in the larval, pupal, or adult forms.

Tardigrada water-bears *(Fig 29)* and acarinæ or water-mites are examples of arachnida.

(7) *Reaction.* Most spring waters are slightly alkaline from the presence of bicarbonate of calcium; magnesium or sodium; $Ca\,H_2\,(CO_3)_2$; $Mg\,H_2\,(CO_3)_2$; $Na\,H\,(CO_3)$.

Occasionally waters show an acid reaction, which disappears on boiling, and in this case is due to CO_2 dissolved. Peaty waters usually show an acid reaction, due to vegetable acids such as crenic ulmic and humic acids.

The reaction is determined by putting drops of water on bits of delicate red and blue litmus papers, or quantitatively by titrating a known quantity of the water with $\frac{N}{100}$ $H_2\,SO_4$, employing lacmoid as an indicator, because it is not affected by CO_2 as is the case with Phenolpthalein. *For explanation of* $\frac{N}{100}$ *and other normal solutions see page 121.*

Fig. 29.

a. Branchipus stagnalis (*Entomostraca*)
b. Cyclops quadricornis (*Entomostraca*)
c. Stentor polymorphus (*Infusoria*)
d. Hydra vulgaris (*Cælenterata*)
e. Tardigrada (*Arachnida*)
f. Actinophrys (*Rhizopoda*)
g. Uvella glaucoma (*Infusoria*)
h. Dinobryon (*Infusoria*)
i. Daphnia pulex (*Entomostraca*)
j. Mona (*Infusoria*)
k. Rotifer vulgaris (*Rotifera*)

Fig. 30.

a. Volvox globator
b. Mona
c. Euglena viridis
d. Euglena longicauda
e. Desmid
f. Oscillatoria
g. Conferva floccosa

h. Lyngbya muralis (*Oscillatoriaceæ*)
i. Tabellaria floccosa (*Diatomaceæ*)
j. Paramecuim (*Infusoria*)
k. Distigma viride (*Euglenia*)
l. Anguillula fluviatilis (*Nematoda*)
m. Euglena viridis
n. Peranema globulosa (*Euglenia*)

Water is the most universal solvent known, there are few substances which will not, even if only to a slight extent, dissolve in water, the diamond and some of the precious metals are a few of the exceptions met with in nature. Waters, whether rain, river, or spring, contain gases dissolved out of the air, by which they are enabled to hold in solution substances otherwise insoluble, conspicuous amongst which is CO_2.

Chemical examination aims at determining the nature and quantity of the dissolved solids.

Spring waters usually contain salts of sodium and calcium, present as chlorides, sulphates, carbonates, bicarbonates, and at times as nitrates, nitrites or phosphates, and in certain waters sulphides are found. In the water from deep wells ammonium salts are often found in amounts, which if present in surface wells, would cause us to condemn the water; in such cases iron salts are sometimes found, since iron salts may act as reducing agents on nitrates brought into contact with them.

The qualitative tests should be most carefully and systematically gone through; a case is recorded where this was neglected, and as a result a water was laid on for the supply of a town which contained so much iron as to be almost a chalybeate water.

Qualitative Tests.

Chlorides. Silver nitrate gives a precipitate soluble in ammonia, but insoluble in dilute nitric acid.

Sulphates. Barium Chloride and dilute hydrochloric acid give, on warming, an insoluble precipitate of $Ba\,SO_4$.

Nitrates. If Brucine be added to water containing nitrates, and strong sulphuric acid added carefully so as to form a layer of about one inch at the bottom of the test tube, a red ring at the junction of the liquids appears which soon turns yellow.

Another test for nitrates is this. To a little of the water in a test tube add an equal bulk of $H_2\,SO_4$, cool the mixture under the tap and pour some solution of ferrous sulphate gently down the tube, taking care to prevent mixing; a brown layer forming at the junction of the fluids indicates nitrates.

Nitrites. Add potassium iodide and starch solutions and acidify with 20 per cent. acetic acid; if nitrites are present an *immediate* blue colour will appear, if not immediate it may be disregarded. Another test is to add to the water some solution of metaphenylenediamine in very dilute sulphuric acid then a few drops of 1 in 3 sulphuric acid, when an immediate yellow or brown colour will indicate nitrites. A control test, using pure distilled water, must always be done, as the metaphenylenediamine solution often has a slight brownish tinge of its own, in fact it is difficult to make a solution of the salt without a brownish tinge.

Or a few drops of the sulphanilic acid and naphthylamine solutions, which are mentioned under quantitive estimation of nitrites, may be added, in which case a rose-red colour indicates nitrites.

Phosphates may be tested for by adding a drop or two of dilute nitric acid and then heating with twice the amount of ammonium molybdate solution to 70° C. when if phosphates be present, a yellow colour will be seen. This test should be repeated with the concentrated water, and a control test done with distilled water. The control test should never be omitted, I have known waters containing large quantities of $Ca. H_2 (CO_3)_2$ when the control has been omitted, reported as containing phosphates, which is of course impossible, calcium phosphate being an insoluble salt.

Phosphates are generally taken to indicate sewage pollution, though as a matter of experience one rarely finds more than a trace of phosphates even in waters showing abundant evidence of animal organic pollution, waters from certain strata which are quite pure will often show heavier traces of phosphates than such impure waters as we have just alluded to, the importance of phosphates in water, is therefore, not great.

Sulphides. To the water in a test tube add a few drops of dilute hydrochloric acid, and hold a filter paper moistened with lead acetate solution over the mouth of the tube, the filter paper is blackened on warming gently if sulphides are present.

If to the original water, on adding a few drops of a solution of nitro-prusside of sodium, a violet-purple colour is produced, it shows the presence of alkaline sulphides.

Ammonia in water is detected by giving a brown or yellowish colour with Nessler's solution. The test is of little importance if the water contains much saline matter, as in that case the test is unreliable; any radicles which may be present, having a greater affinity for the potassium of the KI which keeps the $Hg I_2$ in solution, will decompose it, and instead of $N Hg_2 I H_2O$ di-mercuric-ammonium iodide being formed, which is soluble in slight amounts and gives if in excess a brown precipitate; we have a cloudiness which may, and probably does consist in part of the green iodide Hg_2I_2.

Calcium. Add to the water some ammonium oxalate $(N H_4)_2 C_2 O_4, H_2 O$ a white precipitate forms which is insoluble in acetic or oxalic acid, but soluble in hydrochloric acid.

6 grs. per gallon gives a turbidity.
16 ,, ,, ,, precipitate.

Magnesium. Take 200 cc of the water, add some finely powdered ammonium oxalate, just a little more than enough to combine with all the lime present, shake and set aside for 24 hours, decant and filter half of this (the other half to be kept for the Quantitative estimation) *vide p. 81*, then concentrate down to about 10 cc and add phosphate of sodium, ammonium chloride, and ammonia solutions, set aside for another 24 hours, and examine the crystals, if there be any, with a microscope (1 inch or $\frac{1}{4}$ inch objective): triple phosphate crystals $MgNH_4PO_4$ easily recognized will be seen if Mg be present.

The presence of magnesia, together with excess of chlorides and sulphates without any evidence of organic pollution, points to contamination by sea-water, an opinion which the history of the water will probably support.

Iron. The most delicate test consists in taking 50 cc of the water in a Nessler glass, adding to it 1 cc of strong nitric acid and 1 cc of potassium ferrocyanide solution, a blue colour, Williamson's blue $(Fe_2)_2 \ (Fe(CN)_6)_3$ is seen if iron be present. Control tests with distilled water should be performed at the same time.

NH_4HS if added to a neutral or alkaline water containing iron, gives a black precipitate (FeS) which dissolves at once in HCl dilute.

Lead. NH_4HS gives a brown precipitate not dissolving in dilute hydrochloric acid.

If a water contains lead, it will, when acidified with dilute HCl and freshly prepared H_2S solution added, show a brown precipitate or coloration best seen in a glass tube (such as a Nessler glass) on a white ground, a control test done in a similar manner with water known to be free from lead should be done at the same time.

A few drops of a solution of potassium bichromate $K_2Cr_2O_7$ added to a water containing lead at once renders it turbid.

Dr. Garrett's test for lead is to take $\frac{1}{2}$ oz. of the suspected water, add a drop of dilute HCl, then one drachm of sulphuretted hydrogen solution, and a grain of barium sulphate (powder), shake and set aside, a white precipitate falls which shows a distinct layer, if lead be present, greyish or black in colour, according as the amount is small or great, consisting of PbS on its surface Further remarks on lead in water appear under the heading "Lead in Water" on pp. 100 and 101.

Zinc. If zinc be present in the water, on concentrating a litre of the water an iridescent film is seen upon the surface just before it commences to boil (Thresh), there will also probably be a history of the water having been stored in a galvanized iron tank, and the water will also be a very soft water.

After concentrating the litre of water, to a portion of it add some ammonia chloride solution, then ammonia, mix well, and if it smells strongly of ammonia add three drops of ammonium sulphide—there is a white precipitate; now to a little of the *original concentrated* water add K H O first a little and then more; if there is a whitish precipitate, soluble in excess to a colourless solution, add some ammonium chloride solution, if there is no precipitate or a slight one dissolving in more NH_4 Cl add H_2 S; a white precipitate indicates *zinc*. Another test is, add to some of the sample acidulated with dilute hydrochloric acid and filtered, a little potassium ferro-cyanide, a turbidity or white precipitate indicates zinc.

The danger of zinc poisoning seems to be somewhat overrated, constipation appears to be the chief symptom in cases of chronic poisoning by zinc.

Organic Matter may be detected by adding a few drops of gold chloride solution to about 50 cc of the water and boiling for about 20 minutes, a slight yellowish colour indicates a trace of organic matter, a violet colour rather more, and a black colour shows a considerable amount.

In every sample of water, if possible, a litre should be evaporated down to 20 or 30 cc and qualitative tests for magnesia, nitrates, phosphates and poisonous metals tested for as directed. It often happens that a litre of water cannot be spared for these tests, in which case the concentration must be less complete and a smaller quantity of water taken.

Quantitative Analysis.

The detail for performing the various quantitative estimations and the interpretation of the results obtained, will be given under the account of each particular estimation. Results may be expressed either in parts per 100,000, or in grains per gallon.

If we estimate the amount of a substance in 100 cc of water and express the result in milligrammes per 100 cc this is the same as saying that there are so many parts per 100,000 of that particular substance in the water; similarly, milligrammes per 70 cc of the water gives grains per gallon, the reason being that, in the first instance—

100 cc = 100,000 milligrammes,
in the second, 70 cc = 70,000 ,,
and as there are 70,000 grains in a gallon; milligrammes per 70 cc = grains per gallon. To convert parts per 100,000 into

grains per gallon, multiply the answer by 0·7; and if we wish to convert grains per gallon into parts per 100,000, we must divide the result by 0·7.

The quantitative estimations should be commenced by determining the amount of total dissolved solids, the results so obtained, even if they gave no other indication, would serve as check upon other estimations subsequently made.

Total Solids. The amount of total solids is found by taking 100 cc or any given quantity of the water in a tared platinum dish, evaporating to dryness over a water bath, drying in an air bath at 105·0 C and weighing, after cooling in a dessicator for four minutes, care must be taken not to dry at a temperature which is too high, otherwise salts will be volatilised and water of crystalisation will be driven off. It is also important to weigh the solids as soon as they are cool, and not allow the platinum dish to stand too long, as platinum has the property of occluding gases, and the weight of the dish will thereby be increased, the solids should not be weighed warm, as when the warm dish is placed on the scale pan, it will radiate off heat, and cause the balance to oscillate, which will prevent our obtaining a true weight. (*vide* p. 112).

Example: 100 cc of water were taken in a platinum dish, the weight of which was ascertained before putting in the water to be 36·400 grammes, after evaporation and drying the dish weighed 36·456 grammes, the solids therefore in 100 cc of water weighed 0·56 gramme, *i.e.,* 56 milligrammes, or 56 parts per 100,000 of total dissolved solids.

Having made sure that we have found the correct weight the dish is next taken in a pair of *iron** tongs and held over a Bunsen lamp until it is just red-hot, so as to determine the amount of fixed and volatile solids; we must note carefully whether there is any blackening or smell of burning, any nitrous fumes, or scintillation. Blackening and smell of burning indicate organic matter; nitrous fumes and scintillation indicate oxidised nitrogen.

The dish is cooled and weighed as before, and the weight is now say 36·454 grammes.

36·454	dish and solids.
36·400	dish.
0·054	difference.

The *Fixed Solids* therefore amount to 54 parts per 100,000 *i.e.,* there has been a loss on ignition equal to 2 parts per 100,000, *i.e.,* the amount of *volatile solids.*

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*If the tongs contain lead, the lead coming into contact with hot platinum forms an alloy which destroys the platinum crucible.

The nature of the dissolved solids is of more importance than the actual amount, a really good water should not have more than 50 parts per 100,000, but many good waters have more than this. Sulphate of calcium gives a hard water, highly appreciated by brewers for the purpose of brewing, but which is liable to give rise to constipation, dyspepsia and flatulence if present in excess. Magnesium salts are apt to cause dyspepsia and diarrhœa. Calcium carbonate, if not in excess, is useful, as it prevents lead from being dissolved.

Chlorine is one of the most important substances to be estimated in water, as a general rule we may be certain that a water which does not contain more than 2 parts per 100,000 has not been contaminated by animal organic matter, which includes, amongst other things, urine and sewage, both of which contain considerable amounts of chlorine. If a water contains more than 4 parts per 100,000 of chlorine its origin should be traced, and if from shallow wells or waters liable to become polluted should be regarded as very suspicious. If we find more than 10 parts per 100,000 of chlorine, together with evidence of organic pollution in the form of large amounts of free and albuminoid ammonia, excess of oxidised nitrogen as nitrates, and a large consumption of oxygen, we may be sure that there is organic contamination. Many good waters giving no signs of organic contamination, but showing large amounts of chlorine, were at one time condemned as unfit for drinking purposes, simply on account of the chlorine they contained. In cases such as these the chlorine is doubtless derived from strata containing sodium chloride, derived in times past from the sea, but it may be due to diffusion backwards from the sea, through subsoil water, sodium chloride being more diffusible than some of the other constituents of sea-water, which are consequently absent or else present to only a slight extent.

The estimation of chlorine is a simple matter, the apparatus required consists of a burette graduated to 0·1 cc, and capable of holding 25 cc, or thereabouts, a white porcelain basin with a flat bottom, capable of holding about 140 cc, a piece of glass rod, and two solutions, one of silver nitrate containing 4·79 grammes of $Ag\ NO_3$ to the litre of water, and the other consisting of pure potassium chromate five grammes to the litre, to this last a weak solution of silver nitrate should have been added, until a slight permanent red precipitate formed, which was allowed to settle and removed by filtration; this ensures the removal of every trace of chloride from the chromate solution.

In a neutral or faintly alkaline solution the estimation of chlorides turns upon the fact that as long as there are chlorides present in a solution containing potassium chromate, silver nitrate may be added, and the silver will combine with the chlorine to form silver chloride in preference to forming silver chromate, and it is only when *all* the chloride has combined with the silver that we shall be able to get the red silver chromate formed; as soon therefore as all the chloride has combined with the nitrate, we at once see a blood-red coloration, and this is the moment when we must cease to add standard silver nitrate solution. What occurs may be represented by the following equations taking the case where the chloride present in the water is sodium chloride:—

$$\mathrm{Na\,Cl + Ag\,NO_3 = Ag\,Cl + Na\,NO_3}.$$

When all the chlorine has been used up then we have:—

$$\mathrm{2\,Ag\,NO_3 + K_2\,Cr\,O_4 = Ag_2\,Cr\,O_4 + 2\,KNO_3}.$$

The reason why 4·79 grammes of silver nitrate are dissolved in a litre of water is this:—Taking the atomic weight of Cl as 35·19, 35·19 parts Cl combine with 168·69 parts $\mathrm{Ag\,NO_3}$.

$\therefore$ 1 part Cl combines with—$\frac{168{\cdot}69}{35{\cdot}19}$ $\mathrm{Ag\,NO_3}$ which $= 4{\cdot}79$ parts.

So that in a solution containing 4·79 grammes $\mathrm{Ag\,NO_3}$ per litre each 1 cc will be equivalent to 1 milligramme of chlorine.

If therefore we take 100 cc of the water under examination and add 1 cc of potassium monochromate solution and run in standard silver nitrate until we get the red silver chromate formed, the number of cc's of the standard silver nitrate solution used, will give the number of milligrammes of chlorine in 100 cc of water, and therefore the parts per 100,000 of chlorine in the water.

If we wish to express the result in terms of NaCl instead of in terms of chlorine, we multiply the result by 1·65.

$$\begin{array}{lcc} \text{Because} \quad \mathrm{Na\,Cl} & = & \mathrm{Cl} \\ \quad 22{\cdot}88 + 35{\cdot}19 & & 35{\cdot}19 \end{array}$$

$$\frac{58{\cdot}07}{35{\cdot}19} = 1{\cdot}65\ \mathrm{Na\,Cl} = 1\ \mathrm{Cl}$$

Hardness in water means soap-destroying power. Soaps are alkaline salts of palmitic, stearic, and oleic acids.

Palmitic acid $\mathrm{C_{16}\,H_{32}\,O_3}$
Stearic ,, $\mathrm{C_{18}\,H_{36}\,O_2}$
Oleic ,, $\mathrm{C_{18}\,H_{34}\,O_2}$

The salts of calcium, magnesium and barium, aluminium or iron form insoluble palmitates, stearates, and oleates, which fall as bulky precipitates; as long as there are any of these bases present in a water free to combine with the organic acids in the soap, so long will it be impossible to form a lather; advantage is taken of this property in the estimation of hardness in water, as will be explained subsequently.

Hardness in water is advantageous in one respect, viz: that when a water contains a sufficient amount of calcium carbonate to render it neutral or alkaline, it ceases to dissolve lead.

A hard water is undesirable for cooking purposes because it fails to extract the juices from meat as well as a soft water, it renders vegetables such as cabbage a bad colour, and by reason of the "furring" of kettles, etc., causes a great expenditure of coal.

For drinking purposes a moderately hard water is certainly more palatable, but if the hardness be due to sulphates of lime and magnesia, it is apt to give rise to digestive troubles such as dyspepsia and diarrhœa or constipation. Sunderland is supplied with a water containing magnesia and sulphates equal to 20 parts per 100,000 of $Mg\ SO_4$, and no ill-effects have been reported from the use of this water.

For washing purposes hard waters are most undesirable, more soap is required for reasons already given, and insoluble precipitates moreover tend to be deposited in the meshes of the fabrics in the process of washing, and so interfere with the removal of the dirt.

For steam purposes hard waters are most objectionable, as they throw down a deposit which forms a "fur" or incrustation on boilers, which by being a bad conductor of heat, tends to cause leaking at the rivets and burning of the plates. Should furring occur, and a fissure in it take place, water will come in contact with the metal and an explosion will probably occur, because iron at a temperature just short of a red heat has the power of decomposing water, setting free hydrogen,* which with air forms an explosive mixture.

Hardness in water is described as Total, Temporary and Fixed. The temporary hardness depends upon the fact that $Ca\ Co_3$, which is practically insoluble in water free from CO_2, is soluble in water containing CO_2, which converts it into a bi-carbonate, having the composition $CaH_2\,(CO_3)_2$, if the CO_2 be driven off by boiling or other means, a precipitate of calcium carbonate occurs and the hardness is lessened.

Fixed hardness is generally due to calcium and magnesium sulphates, or to a less extent to nitrates, chlorides or phosphates. It is the hardness due to these salts, and especially the sulphates, which gives rise to the hard incrustations on boilers, so difficult to remove.

Calcium sulphate is most soluble at 95° F., so that if the

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* $Fe_2 + 3\,H_2O = Fe_2\,O_3 + 3\,H_2$

temperature of the water exceeds this, the higher the temperature the greater the deposit. In high pressure boilers it is not advisable to use waters containing even traces of sulphates, as at the high temperatures attained the salt is quite insoluble

Anti-incrustators are occasionally added to waters to prevent this deposit. Sodium carbonate acts as an anti-incrustator, thus $Na_2 CO_3 + Ca SO_4 = Ca CO_3 + Na_2 SO_4$, a precipitate of $Ca CO_3$ being much more easily detached than one of $Ca SO_4$, and $Na_2 SO_4$ is a soluble salt.

Maignen's 'Anti-Calcaire' for softening water is a powder consisting of alum, lime, and sodium carbonate. The alum forms a bulky precipitate with the lime, which mechanically carries down any organic matter in the water, calcium sulphate is formed, which is in turn attacked by the sodium carbonate, and if there are any magnesium salts, these are also attacked by the sodium carbonate, and an incrustation formed, which however is easily removed.

Boiler incrustations, due to removable and permanent hardness, consist chiefly of—

$$Ca CO_3,\ Ca SO_4, \text{ and } Mg H_2 O_2.$$

The $Ca CO_3$ and $Ca SO_4$ are thrown down in the manner already described, the $Mg H_2 O_2$ is thought to be due to $Ca CO_3$ acting upon $Mg Cl_2$, thus $Mg O + Ca Cl_2$ are first formed, and then $Mg O$ is speedily converted into $Mg O H_2 O$ by the action of water.* It often happens that an opinion is required not only as to the suitability of a water for drinking or other domestic uses, but also for steam purposes, hence the allusion to boiler deposits. Waters collected near the sea generally contain sea-salts, and the amount and nature of fixed hardness in such waters becomes of great importance if these waters are liable to be used at any time for steam purposes.

For drinking and domestic purposes generally, the fixed hardness should not exceed 5 to 7 grains per gallon, *i.e.*, 7 to 10 parts per 100,000, and the total hardness ought not to exceed 21 grains per gallon, *i.e.*, 30 parts per 100,000.

Soft waters contain less than 7 parts per 100,000 of total hardness. A moderately hard water contains between 7 and 14 parts per 100,000, and water is distinctly hard if it shows over 14 and under 28 parts per 100,000; very hard if more than this is present. The soap test as devised by Clark is still the most convenient method, since acidimetry, another method sometimes applied to the estimation of hardness

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* $Mg O H_2 O$ may be due to $Mg Cl_2$ and H_2O becoming decomposed, HCl and $Mg O H_2O$ being formed.

requires very accurate solutions, necessitating most careful preparation and no little experience in use.

In performing Clark's test the solutions required are—

(*I.*) A standard solution of a stable salt of lime, such as calcium chloride, of such a strength that 50 cc shall be equivalent in soap-destroying power to 10 milligrammes of $Ca\,CO_3$.

(*II.*) A soap solution of such strength that 11 cc or thereabouts are equivalent to 50 cc of the lime solution above mentioned.

(*III.*) A stock of recently boiled distilled water free from CO_2.

(*IV.*) Three bottles with wide mouths of about 150 cc capacity.

(*V.*) A burette graduated to $\frac{1}{10}$ cc.

(*IV.*) A 50 cc pipette or 50 cc measure glass.

The lime solution is prepared by taking 200 milligrammes of dry pure precipitated $Ca\,CO_3$ and dissolving it in water with the aid of a few drops of dilute hydrochloric acid, evaporating to dryness over a water-bath, adding more distilled water, and repeating the process at least three times in order to ensure the driving off of any free hydrochloric acid, the salt is finally dissolved in a litre of pure distilled water, and the solution is ready for use, 50 cc of which are equivalent in soap-destroying power to 10 milligrammes of $Ca\,CO_3$.

It is important to remember that so long as we have a certain quantity of calcium, it makes no difference whether the salt employed be a carbonate, bicarbonate, sulphate, nitrate, or chloride, the *radicle* is immaterial.

If we had acted on the $Ca\,CO_3$ then with $H\,N\,O_3$, $H_2\,SO_4$ or $H_2\,CO_3$, theoretically it would make no difference, but in the case of $H\,N\,O_3$ and $H_2\,SO_4$ we should have experienced great difficulty in removing any excess of acid there might be, and in the case of $H_2\,CO_3$ we should have an unstable salt liable to precipitate $Ca\,CO_3$ if any of the CO_2 holding the $Ca\,H_2\,(CO_3)$ in solution was lost, so $Ca\,Cl_2$ is selected, it being free from all these defects.

The soap solution, should be of such strength that 11 cc approximately equals 10 milligrammes of $Ca\,CO_3$, this can be made by taking 10 grammes of air-dried Castille soap cut into fine slices, and dissolving them in a litre of dilute alcohol sp. gr. 0·949 (43 per cent by volume). The solution is best left unfiltered, although many people advise filtering, and if the solution becomes turbid it must be shaken up before being used.

Soap solutions never remain of constant strength, so it must be titrated against standard lime solution every day it is used.

Detail for performing the soap test to find the total hardness.

Take 50 cc of the standard lime solution, in one of the wide-mouthed bottles previously mentioned, run in soap solution from the burette, shaking after each addition, until an uniform beady lather $\frac{1}{4}$-inch thick is formed, which lasts at least 2 minutes when the bottle is laid on its side, the lather should cause the water when shaken to give a dull soft sound, which is almost as good an indication as the appearance of the lather; note the number of cc soap solution used and call this number L.

It is necessary to determine how much soap solution is required to give a lather with 50 cc of pure recently boiled distilled water; this is therefore done in a manner precisely similar to the preceding, because the purest distilled water requires a certain amount of soap to form a lather; call this D.

Lastly take 50 cc of the sample, and find how much soap solution is required to give a lather precisely similar to the two preceding, and call the amount so used S.

If from L and S we subtract D (because both the lime solution and sample may be regarded as 50 cc of distilled water + 10 milligrammes and x, milligrammes of $CaCO_3$ respectively) then by rule of three we say—

If L — D = 10 mgms. $CaCO_3$ how much will S — D equal

$$\text{so } L - D : S - D :: 10 : x$$

$$\text{i.e. } \frac{S - D \times 10}{L - D} = x$$

or the number of milligrammes $CaCO_3$ in 50 cc of sample, and this multiplied by 2 gives the result expressed in *terms* of $CaCO_3$ in parts per 100,000. Hardness is frequently expressed in grains per gallon or degrees of Clark's scale, this is done by mutiplying results expressed in parts per 100,000 by 0·7.

Fixed Hardness. Temporary hardness is eliminated by boiling down 200 cc of the sample to about 70 cc, again making up to 200 cc with cool recently-boiled distilled water, which should then be mixed and 50 cc decanted, and if necessary filtered and tested precisely as was done when estimating total hardness. The hardness now found to be present is *fixed* hardness, and this subtracted from the total hardness gives the amount of *temporary* or *removable* hardness.

Magnesia can be estimated by the soap test, after first removing the lime salts which may be present.

Detail. Take about 100 cc of the water, to which ammonium oxalate was added when testing for magnesia (*page 73, q. v.*) which was shaken well and set aside for at least 24 hours, decant, filter, and determine the amounts of hardness in one or two amounts of 50 cc in precisely the same way as before, having then calculated the amount of hardness remaining in the water after the removal of the lime, as if it were due to $Ca\ CO_3$, this can be expressed in terms of $Mg\ CO_3$ by multiplying the results by 0·56, because one part of $Ca\ CO_3$ is equivalent in soap-destroying power to 0·56 parts of $Mg\ CO_3$.

In very hard waters, especially in cases where the hardness is in part due to magnesium salts, care must be taken not to take the scum, which is apt to form in such waters, for the true lather, in any case when determining hardness in water, if the water be very hard, it is better to take some aliquot part of 100 cc, say 10 cc, 20 cc, or 25 cc, make up to 50 cc with recently-boiled distilled water, and in making the calculation allow for the dilution.

Organic matter in water may be either vegetable or animal, the former is comparatively unimportant and the latter very important, the principal object aimed at in an examination of water, is to find out whether or not there has been animal organic pollution.

Wanklyn's Process.—This process was devised by Mr. J. A. Wanklyn and Mr. E. T. Chapman. It depends upon the fact that all organic matter which is likely to be a source of danger in water is nitrogenous, and this in nature tends to resolve itself into simpler compounds by the process of decay, effected by oxygen and micro-organisms with the result that CO_2, H_2O, NH_3 N_2O_3 and $N_2\ O_5$, are formed, when these processes are complete, the nitrogenous matter will be detected as nitrates, nitrites and ammonia, the ammonia existing as salts, such as ammonium-sulphate, chloride, or nitrate. When urea gains access to water it is speedily converted into ammonium carbonate which then appears in the first stage of the Wanklyn process as free or saline ammonia. The first stage consists merely in distilling a certain quantity of the water, and determining by a colorimetric method the amount of ammonia in the distillate. In the second stage, nitrogenous organic matter existing as such is decomposed by means of an oxidising agent ($K_2\ Mn_2\ O_8$) and a hydrating agent ($K\ H\ O$), by which action ammonia is formed; the ammonia formed in this way indicates actual contamination existing at the time of the examination and is known as albuminoid ammonia.

The manner in which it distils over is a matter of importance, ammonia derived from animal organic matter comes over chiefly in the first two quantities of 50 cc distilled, and in the succeeding quantities the ammonia will not be so marked, whereas when the albuminoid ammonia has been derived from vegetable organic matter, the ammonia will distil over more gradually. Requirements—some means for boiling water such as gas with a Bunsen burner, or a spirit lamp which gives a large flame, and in addition certain apparatus as follows—

(*I.*) A distilling apparatus. Of these there are many varieties in use; in some laboratories a still, known as a Liebig's Condenser is used, this consists of an inner tube

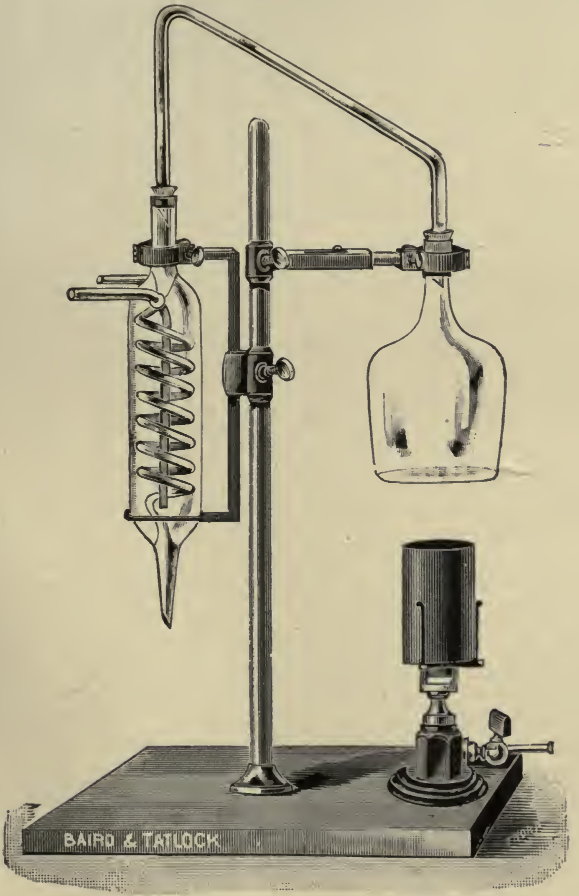

Fig. 31.—Spiral Condenser.

through which the steam from the flask serving as a retort passes, and an outer one which serves as a water jacket in which cold water is made to circulate in order to condense the steam which passes through the inner tube. At the two ends, where the condenser is connected to the flask serving as a retort, and to the adapter for leading into the collecting vessel respectively, the joints are rendered air-tight either with strips of guttapercha tissue, or the joint between the retort and condenser may be made with an ordinary indiarubber umbrella ring, cleansed by being soaked in dilute K H O or Na H O. A more convenient apparatus is that known as a spiral condenser *(Fig. 31)* consisting of an outer jacket in which water is made to circulate outside a strong spiral worm which passes through it and is fixed in position by being fused into it in the manner shown in the illustration. The worm is connected to the flask by a bent glass tube.

(*II.*) A series of narrow cylinders of uniform calibre and height, made of colourless glass, and each marked at the 50 cc level, a very convenient size is 15 centimeters high, and 2·8 centimeters in diameter; these glasses are known as Nessler's tubes.

(*III.*) Either a burette graduated to tenths of a cc (for delivering 2 cc Nessler's solution to each 50 cc of distillate and to each 50 cc standard solution for comparison), or else a 2 cc pipette, if the latter is used there is less liability of adding an unequal quantity of Nessler's solution to the tubes when comparing the colours.

(*IV.*) A burette graduated to tenths of a cc for delivering accurately certain quantities of ammonium chloride solution when making the standard solutions for comparison.

(*V.*) A 50 cc measure for measuring alkaline permanganate solution and

(*VI.*) A half-litre flask for measuring 500 cc of the water.

In Wanklyn's process the solutions required are :—

(*I.*) Nessler's solution. This is best obtained from a reliable firm, ready for use, but it can be made in this manner: 35 grammes of K I are dissolved in 100 cc of distilled water, 17 grammes of $Hg\,Cl_2$ are dissolved in 300 cc of distilled water; the perchloride may be heated to effect solution, but must be cooled afterwards, then added to the K I solution until a permanent red precipitate of $Hg\,I_2$ is formed. The mixture is then made up to a litre with 20 per cent. solution of Na HO, after which a little more of the $Hg\,Cl_2$ is added until a precipitate again forms; when mixed, it must be set aside in a stoppered bottle and the precipitate allowed to subside, then the clear solution is decanted off into well stoppered bottles and kept for a time before use. Keeping improves it.

Nessler's solution gives with ammonia or its salts a yellow or brown colour, or brown precipitate of NHg_2IH_2O (Dimercuric-ammonium iodide).

(*II.*) A stock of pure distilled water, free from ammonia. This is made by taking the purest distilled water obtainable, and distilling until all traces of ammonia have ceased to come off, the residue left in the flask will then be free from ammonia and should be kept in a perfectly clean glass stoppered bottle.

(*III.*) A solution of ammonium chloride of such a strength that 1 cc will contain 0·01 milligramme of NH_4Cl. This is known as the standard ammonium chloride solution, and when ammonium chloride solution is subsequently mentioned, this will be the one referred to, 1 cc of which equals 0·01 milligramme of NH_3.

A solution of this strength will not keep so well as a stronger one, a stock solution is therefore made and diluted when required to the proper strength by taking 1 cc and diluting to 100 cc with pure distilled water.

The *stock* solution contains 3·136 grammes of ammonium chloride in a litre of water, 1 cc of it equals 1 milligramme of ammonia for the following reasons :—

$$\begin{array}{lcrcrcr}
NH_4Cl & & & = & NH_3 + HCl & & \\
N & = & 13{\cdot}94 & & N & = & 13{\cdot}94 \\
H_4 & = & 4{\cdot}00 & & H_3 & = & 3{\cdot}00 \\
Cl & = & \underline{35{\cdot}19} & & & & \underline{\phantom{16{\cdot}94}} \\
 & & 53{\cdot}13 & = & & & 16{\cdot}94
\end{array}$$

53·13 grammes NH_4Cl = 16·94 grammes NH_3

$$\text{therefore } \frac{53{\cdot}13}{16{\cdot}94} = 1 \text{ gramme } NH_3$$

and this = 3·136 of NH_4Cl. So the stock solution containing 3·136 grammes per litre gives a solution, 1 cc of which = 1 milligramme NH_3, and if 1 cc of this be made up to 100 cc with distilled water, 1 cc will be equivalent to 0·01 milligramme NH_3.

Process. 500 cc of water are placed in a flask, and a few drops of sodium carbonate solution added if the water is not alkaline, the flask is then connected with a distilling apparatus and distillation performed, the distillate is collected in 50 cc Nessler glasses, 150 cc should be distilled, but it will, as a rule, be found that all the ammonia has come over in the first two 50 cc quantities.

As soon as the distillate is over, similar Nessler tubes, which are perfectly clean, are taken, and a series of "*standards*" for comparison prepared, which are labelled as follows:—No. 1, No. 2, No. 3, No. 4, No. 5, and No. 6.

Into No. 1 is run 0·5 cc of the NH_4 Cl solution.
" 2 " 0·75 " " "
" 3 " 1·00 " " "
" 4 " 1·5 " " "
" 5 " 2·0 " " "
" 6 " 2·5 " " "

Or the series may commence with 0·25 cc and be extended to 3·0 cc. Having added the NH_4 Cl solution to each of the standards as detailed, make each up to the 50 cc mark with pure ammonia-free water, and then add to each 2 cc of Nessler's solution, and immediately afterwards add 2 cc of Nessler's solution to the three 50 cc tubes containing distillate.

The first 50 cc will probably have a slight yellow colour, and the other two little or none. With the first stage of Wanklyn's process, *i.e.*, the estimation of free or saline ammonia, it is not necessary to compare all three of the distillates with the standards, only the first of the series need be compared since $\frac{3}{4}$ of all the NH_3 has been found by numerous experiments to come over in the first 50 cc distilled.

The first 50 cc is therefore alone compared with the standards, and the colour is for example found to correspond with No. 2. Now No. 2 in the series shown above contains 0·75 cc NH_4 Cl solution.

∴ All the free or saline NH_3 in 500 cc of the water

$$= 0{\cdot}75 \text{ cc} + \frac{0{\cdot}75}{3} \text{ this} = 0{\cdot}75 + {\cdot}25 \text{ which} = 1 \text{ cc}$$

but 1 cc = ·01 milligramme NH_3
∴ 500 cc contain 0·01 milligramme NH_3
and 100 cc " 0·002 " "

i.e., 0·002 parts per 100,000 of free or saline ammonia.

In the case of a water containing so large an amount of free ammonia that it gives a colour darker than any of the standards; a portion of it must be taken and diluted up to 50 cc, the colour in this matched with one of the standards, and the amount of dilution taken into consideration.

For example, the first 50 cc of distillate from a sample was so dark, that when compared with the standards there were none equal to it, 25 cc of it were therefore taken and diluted to 50 cc with pure distilled water, and then it was found to match No. 5, which contained 2·0 cc NH_4 Cl solution ∴ since this contained only 25 cc of distillate the 50 cc = 4·0 cc, and the whole sample = 4 + $\frac{4}{3}$ = 5·333 which × by ·01 = ·05333 per 500 cc, divide this amount by 5, and we get ·010666 per 100 cc, *i.e.,* parts per 100,000.

Lastly, to the residue left in the flask, which it is presumed contains some nitrogenous organic matter, is added

50 cc of an alkaline solution of potassium permanganate and (some ammonia-free water must be added if the residue left in the flask has been much reduced by the previous distillation) then distil and collect the distillate in 50 cc Nessler tubes as was done in the first stage of the process.

The alkaline permanganate solution is prepared by dissolving 200 grammes of KHO and 8 grammes of $K_2Mn_2O_8$ in 1200 cc of distilled water, which is then concentrated by boiling rapidly until when cool it measures 1 litre, this should be kept in a well stoppered bottle ready for use.

Before use, as an additional precaution, it is a good plan to place 50 cc of the alkaline permanganate in a flask with 100 cc of pure distilled water, and boil for ten minutes, the alkaline permanganate is then free from all NH_3 (possibly absorbed since it was first prepared), and this solution can now with safety be added to the residue in the flask and distillation commenced. As distillation proceeds, the distillate is collected in 50 cc Nessler tubes, previously numbered, and these, when all the ammonia has distilled over (which is ascertained by testing a little of the distillate in a test tube, with a few drops of Nessler's solution) are compared with the standards, only in this case, *each* successive 50 cc must be matched, and the total amounts of NH_4 Cl to which they are equivalent ascertained. For example:

No. 1 distillate matches No. 3 standard.
No. 2 ,, ,, No. 2 ,,
No. 3 ,, ,, No. 1 ,,
No. 4 ,, contained no NH_3

Then all the NH_3 derived by the use of the alkaline permanganate solution equals :—

1 cc + 0·75 cc + 0·5 cc of NH_4 Cl solution.
i.e. 2·25 cc.

and each 1 cc = ·01 mgm. NH_3

∴ 500 cc of the sample contained albuminoid or organic ammonia equivalent to 2.25 cc of NH_4 Cl solution, and since each 1 cc = 0·01 mgm. NH_3, therefore 2·25 cc NH_4 Cl solution = 0·0225 mgm. NH_3

i.e. 500 cc = 0·0225 mgm. NH_3
and 100 cc = 0·0045 ,, ,,
i.e. 0·0045 parts albuminoid ammonia per 100,000.

In regard to the conclusions to be drawn from the above estimations, all rain—or snow-water, especially that collected near a town, shows a certain, and often considerable amount of free ammonia, as a rule it amounts to about 0·028 part per 100,000; but this rain-water, if not further contaminated by the washings off roofs, surface washings, or other pollution, will show little albuminoid ammonia.

The water from shallow wells will, if uncontaminated, show little or no free ammonia, and only a trace of albuminoid ammonia. All the ammonia which reaches the soil, if the process of filtration through the superficial layers of the earth be uninterrupted, is seized by plant life for its support; but if the natural process of filtration be interfered with, and water which has not undergone this process of natural filtration through the superficial layers of what has been called the "living" earth gets into the well, then the free and albuminoid ammonia will be present, and present in large amounts, so that in the case of shallow well-water, a large amount of free and albuminoid ammonia always means that unfiltered filth, that is filth which has not been exposed to the nitrifying ferments, has gained access to the well. The circumstances under which filth may gain access to a well without undergoing natural filtration, are where a leaky drain allows its contents to flow beneath the superficial layers of the earth, or where there is a leaky cess-pool, etc., or where the surface washings from manured land gain direct access to the water supply, as often happens, in unprotected water supplies. There is also another source of pollution which must not be overlooked, this is the case where the water supply is intermittent. Pipes alternately full and empty are very liable, if there be a leak, to suck in any liquids or gases through which the pipes may pass, just as a Bunsen lamp draws air into it when it is alight. The conclusions to be drawn in the case of waters from deep and shallow wells are different. In deep wells the amounts of saline ammonia are frequently somewhat excessive, and these may be disregarded if unaccompanied by other evidence of pollution, although these amounts would, as we have already said, if present in a shallow well, justify the condemnation of the water. The origin of the ammonia in deep well waters is the subject of much speculation; in some cases it may be due to ammonia salts deposited in the deeper layers of the earth, or what is more likely, is that it is due to nitrates in solution coming in contact with iron salts, which act as reducing agents. The pipes which carry water have been known to act in this way, and it is of great importance to determine whether iron is present, even in traces, in the case of a water showing much saline ammonia.

Deep wells, uncontaminated, showing much saline ammonia would show little or no albuminoid ammonia, and other evidence of contamination by animal organic matter would be wanting.

Bearing in mind these facts, we must consider albuminoid ammonia as the important substance upon which a water's reputation stands or falls, albuminoid ammonia indicates present danger, its source must therefore be determined, if of *vegetable* origin and relatively unimportant as in peaty waters, it will distil over gradually, there will be small amounts of chlorides and little or no oxidised nitrogen; when of *animal* origin, and therefore dangerous, it will distil over rapidly, principally in the first two 50 cc tubes of distillate, and this will be accompanied by much free ammonia, and the presence of chlorides and oxidised nitrogen as nitrites and nitrates.

Free ammonia in a polluted water is due as a rule to urea which, as is well known, is speedily hydrated and converted by means of the micrococcus ureæ into ammonium carbonate. Wanklyn says "when the free ammonia exceeds 0·08 part per million, it almost invariably proceeds from the fermentation of urea into carbonate of ammonia, and is a sign that the water in question consists of diluted urine in a very recent condition. In these cases the water will likewise be found to be loaded with chlorides." These waters will also show an excessive and generally very excessive amount of albuminoid ammonia. A small amount of free ammonia and albuminoid ammonia not exceeding 0·008 of albuminoid ammonia will generally indicate an uncontaminated water.

Free ammonia amounting to 0·005 part per 100,000 and albuminoid ammonia amounting to 0·008 will generally indicate a water just on the border line, if there be excess of chlorides and nitrates, the water will generally be found to be contaminated by animal organic matter; if not, and there is no evidence of contamination, it may be considered fit for use. Much albuminoid and little free-ammonia, accompanied by small amounts of chlorides and oxidised nitrogen, points to vegetable contamination, and frequently indicates water from an upland surface where peat abounds. The following table is a summary of conclusions based upon the amounts of free and albuminoid ammonia found:

Amounts in parts per 100,000.		
Free NH_3	Albuminoid NH_3	Conclusions.
Nil	Considerable, say 0·01	Probably of vegetable origin such as peat.
Much free, say 0·01	Little or none under 0·003	Probably rain water
0·002 or under	0.008	Water pure
0·005	0·008	Probably pure, but on border-line of safety
0·01	0·01	Very suspicious, probably polluted with urine
0·008 or over	0·01	Urine or sewage

Nitrates. These salts represent the ultimate stage of oxidation of nitrogenous organic matter, and therefore indicate old rather than recent contamination. In certain strata nitrates are present, and it is impossible to say how long a time they have been where they are, possibly they have arrived there by a process of infiltration or diffusion; the whole process of diffusion of salts through porous soil is most complicated, certain salts diffuse quickly, others diffuse very slowly. Nitrates in a water are usually present as nitrates of soda, or lime, more rarely as nitrate of potassium, and in analytical results one generally expresses nitrates as N_2O_5 since nitric acid may be regarded as $N_2O_5 + H_2O = 2HNO_3$, calcium nitrate as $N_2O_5 + CaO = Ca(NO_3)_2$, sodium nitrate $N_2O_5 + 2Na + H_2O = 2NaNO_3 + 2H$. Nitrates expressed as N_2O_5 should not exceed 5·5 parts per 100,000.

Expressed as nitrogen this would be $\dfrac{5\cdot5 \times 27\cdot88}{107\cdot28} = 1\cdot43$ N

i.e. taking the atomic weight of N as 13·94, and that of O as 15·88.

There are several methods of estimating nitrates present in water. Two of the methods, the Aluminium and Zinc-copper couple depend for their action on the fact that in these processes nascent hydrogen is formed, which acts as a reducing agent, converting nitrates into ammonia—

thus $HNO_3 + 4H_2 = NH_3 + 3H_2O$.

In the aluminium process a strongly alkaline solution is made by dissolving 100 grammes of pure NaHO in a litre of distilled water, to which is added about six square inches of aluminium foil, which has been heated to just short of redness by wrapping it round a piece of glass rod, and holding it for a few seconds in the flame of a Bunsen or spirit lamp; the solution is then corked and left for some hours. The object of adding the aluminium foil to this, is to ensure the conversion into ammonia of any nitrates accidently present in the reagent, ammonia so formed is then removed by boiling, and the solution is once more made up to the litre with pure distilled water known to be free from all trace of ammonia.

A solution of one of the caustic alkalies in water has the power of attacking metallic aluminium, with the result that hydrogen is evolved; this reaction may be represented as follows:

$$Al_2 + 2\,NaHO + 2H_2O = Al_2Na_2O_4 + 3H_2.$$

Aluminium, caustic soda and water yield aluminate of soda and hydrogen gas. The second part of the reaction in which the nitrate is reduced, is represented thus; where M' signifies an univalent metal

$$4H_2 + M'NO_3 = NH_3 + M'HO + 2H_2O.$$

Hydrogen and nitrate, yield ammonia, a hydrate of the alkaline base, and water.

Detail:—Add to 100 cc of the sample water in a flask 100 cc of the alkaline solution, previously described, and also about two square inches of aluminium heated to just short of redness in the manner already mentioned; cork up the flask and set aside for some hours, at the end of which, distil as in the Wanklyn process. The qualitative tests will have shown whether or not there is likely to be a large quantity of ammonia resulting from the action of this process, if there is, distil over about 120 cc, mix the distillate and take a certain portion of it, say 10 or 20 cc, make up to 50 cc with distilled water, add 2 cc Nessler's solution and compare with standards as in the Wanklyn process. Before estimating the nitrates by this method, it will be necessary to know how much free ammonia the water contains, and also what quantity of nitrites exists in the water. These amounts expressed as NH_3 must be subtracted from the NH_3 found by the aluminium process, and the result will be ammonia derived from the reduction of nitrates, which can then be expressed either as nitric nitrogen, N, or as N_2O_5.

An example will perhaps make this clear:—After employing the aluminium process, 120 cc were distilled; as the sample contained a good deal of nitrates, only 20 cc were taken; this quantity diluted to 50 cc, Nesslerised, and compared with the standards as detailed, was found to match the standard containing 2 cc of NH_4 Cl solution.

i.e., 20 cc of the 120 cc = 2 cc NH_4 Cl solution ∴ 120 cc $= \frac{2 \times 120}{20} = 12$ cc, but each 1 cc = ·01 mgm. NH_3.

∴ 12 cc = ·12 milligramme NH_3 in 100 cc of the sample water since there were only 100 cc of the actual sample taken.

Now all of this NH_3 is not attributable to nitrates, for let us assume 0·005 milligramme per 100 cc of free ammonia were found in the water and 0·056 milligramme NH_3 were derived from nitrites present, that is to say 0·005 + 0·056 which = 0·061 must be subtracted from the total 0·12 milligramme, leaving 0·059 milligramme per 100 cc of NH_3 derived from nitrates.

To express this as nitric N, we must multiply by 14 and divide by 17, because $N : NH_3 :: 14 : 17$ and to express it as N_2O_5 we must multiply by 108 and divide by 34, because $2\,NH_3 : N_2O_5 :: 34 : 108$, or in other words multiply by $\frac{108}{34}$ which = 3·176, so that in the above example the nitric nitrogen would have been 0·048 per 100,000, and nitrates as N_2O_5 would have been 0·1873 per 100,000.

Zinc-copper couple; this process requires a certain amount of saline matter in the water in addition to any nitrates, which were first ascertained to be present by the qualitative tests, so that in the case of very soft waters a small amount of pure sodium chloride (0·1 gramme per 100 cc) should be first added.

Apparatus required. A 6 ounce wide-mouthed stoppered bottle, some zinc foil, and a solution of cupric sulphate, made by dissolving 30 grammes copper sulphate in a litre of distilled water; distilling apparatus and Nessler glasses as in the Wanklyn process. Detail:—Having cut a piece of clean zinc-foil about 3 inches by 2 inches, immerse it for about three minutes in the copper sulphate solution, then pour off the copper solution and wash the zinc (which must be firmly coated with a deposit of metallic copper, black in colour), first with pure distilled water, and then with sample water. Into the wide-mouthed stoppered bottle put the zinc (which, prior to the coppering process, has been corrugated by folding it several times, and then pulling it out again), add 100 cc of the sample water, close the bottle with the stopper and place it in a warm cupboard (temp. 25° to 30°C.) for at least 12 hours, after which transfer the water to the flask of a distilling apparatus, add 200 cc of pure ammonia-free distilled water, distillation is then commenced and the distillate collected until the NH_3 has come over, an aliquot part of this distillate which was collected in a receiving flask is then taken and Nesslerised, and the calculation and deduction for free ammonia and nitrates previously estimated is made as detailed under the description of the aluminium process.

A colour method for the estimation of nitrates, which is very simple in mode of action, is conducted as follows—

Apparatus. Two platinum dishes capable of holding at least 70 cc, three clear glass cylinders of uniform calibre capable of holding 100 cc, with a mark at 100 cc, a graduated measure, and the following reagents—

I. Phenol-sulphonic acid, made by taking 37 cc of strong sulphuric acid (free from nitric acid) and adding to it 3 cc of distilled water and 6 grammes of pure phenol.

II. Liquor ammonia. S.G. 0·891.

III. Standard solution of potassium nitrate, made by dissolving 0·72 gramme of KNO_3 in a litre of water 1 cc = 0·1 milligramme of nitric nitrogen.

$$\underset{38{\cdot}83 + 13{\cdot}94 + (15{\cdot}88)3}{\text{thus } KNO_3} \quad \text{contains} \quad \underset{13{\cdot}94}{N}$$

$$\therefore \text{ 1 gramme of N is contained in } \frac{100{\cdot}41}{13{\cdot}94} = 7{\cdot}203 \text{ gms. } KNO_3$$

∴ if we take 0·72 gramme KNO_3 and dissolve it in a litre of water 1 cc will contain 0·0001 gramme of N, *i.e.* 0·1 milligramme N.

IV. Pure sulphuric acid.

V. Pure ammonia-free distilled water.

The test is performed thus—(having first determined qualitatively whether there be a large or small quantity of nitrates in the water), (*a*) take from 20 to 100 cc of the sample, place it in a platinum dish and evaporate to dryness over a water bath, (*b*) in another platinum dish place either 5 cc or 10 cc of the standard nitrate solution, evaporate to dryness over a water bath.

To (*a*) and (*b*) add 2 cc of phenol-sulphonic acid solution, thoroughly mix with a clean glass rod, and then add to each 1 cc of distilled water and 3 drops of strong sulphuric acid, and warm for a few minutes over the water bath, after which to each add 25 cc of strong ammonia, pour into the 100 cc tubes, taking care to label each one as it is poured out, then make up each to 100 cc with pure distilled water, if they match in colour there is nothing more to do but calculate the amount of nitrogen, if they do not, and (*a*) is found to be darker than (*b*), take a third 100 cc tube exactly similar to those previously used, and pour into it sufficient of the fluid in tube (*a*) to give a depth of colour matching (*b*); say for example 30 cc of (*a*) matched the standard (*b*), and (*a*) contained the residue from 50 cc of the sample of water evaporated to dryness, and (*b*) contained, let us say 10 cc of potassium nitrate solution which is equal to 1 milligramme of nitric nitrogen.

$$30 \text{ cc of } a = 1 \text{ milligramme N}$$

$$\therefore 50 \text{ cc} = \frac{50 \times 1}{30} = \tfrac{5}{3} = 1\text{-}\dot{6}\dot{6}$$

∴ 50 cc of the water contain nitrate equal to $1{\cdot}\dot{6}\dot{6}$ milligramme of nitrogen, and 100 cc will contain 3·32 milligramme, *i.e.* 3·32 milligramme per 100,000, an amount which is generally allowed to be excessive. A water should not contain nitrates to the extent of more than 1·428 part per 100,000 expressed as nitric nitrogen (N), or expressed as N_2O_5, nitrates should not amount to more than 5·51 parts per 100,000.

In judging the colours in colorimetric analysis, advantage is taken of the fact that in solutions which are coloured by the same substance, the depth of colour is dependent on two things, degree of concentration and height of the column viewed; now if one of these contain a known amount of the substance, and these solutions be placed in clear glass cylinders of equal calibre, similar in fact in every respect, then the degree of concentration can be determined by noting the depths of fluid which causes the tints of colour to coincide, as an experimental proof let us take a solution of methylene blue 0·001 milligramme per litre, and put this in a tube 12 c.m. high, then take some solution of the same substance, but twice as strong, in this case the same tint will be seen as we got with the first solution but with a depth only equal to 6 c.m., by this it is known that an equal volume of this solution contains twice as much of the colouring matter as the standard, since the same colour is given with a column only half as deep. Take another case, if 50 cc of the solution under examination give a match with 100 cc of that first mentioned when placed alongside one another under precisely similar conditions in regard to light and containing vessels, then it may be assumed that the sample under examination is twice as concentrated as the standard, since half the quantity when placed in a cylinder of size equal to that holding the standard fluid, gives the same depth of colour. The results obtained by this method are sufficiently accurate to be relied on. For colorimetric analysis, a special apparatus, depending for its action on these facts, and known as Stokes' colorimeter (*Fig. 32*), has been devised, which enables one to alter the level of the fluid in a standard tube

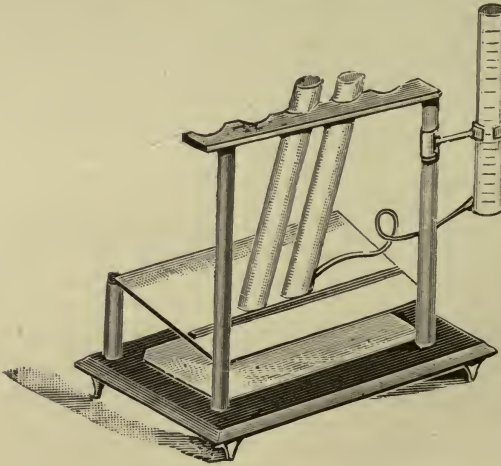

Fig 32—STOKES' COLORIMETER.

by means of a moveable tube supported by a metal arm, this tube is placed in connection with it by a rubber tube carrying a pinch-cock, and at the same time one can read off the volume of the standard which gives the same depth of colour as the known volume of fluid under examination, the strength of which we are trying to ascertain.

Nitrites. Except in the case of rain-water, which often contains nitrites in solution derived from nitrous acid present in the air, traces of which are known to be present after electrical disturbances, nitrites invariably indicate animal organic pollution, and waters containing nitrites must have suffered very recent pollution, since nitrites are formed prior to the more complete oxidation into nitrates.

If the qualitative tests show nitrites to be present, it is advisable to find out the extent to which they are present; this may be done either by Griess's method or by Ilosvay's test.

Griess's test depends for its action on the formation of Bismark Brown with metaphenylene-diamine if nitrites are present, and requires for its performance a burette graduated to 0·1 cc; two 1 cc pipettes; six 100 cc glass cylinders of uniform calibre with a mark at 100 cc.

Reagents:—

I. Dilute sulphuric acid (1 : 2 of water).

II. Solution of metaphenylene-diamine, 5 grammes in a litre of water, slightly acidified with sulphuric acid.

III. A solution of sodium nitrite of such a strength that 1 cc contains 0·01 milligramme N_2O_3. It is impossible to get the required solution by dissolving the sodium or potassium salt directly, so the solution has to be made as follows:—0·406 gramme of dry silver nitrite is taken and dissolved in hot water, then pure sodium chloride added, until it ceases to form a precipitate, and the solution is next made up to a litre with distilled water, this is set aside in the dark until it has entirely cleared, then 100 cc of the clear solution are decanted carefully and diluted to 1 litre; 1 cc will contain 0·01 milligramme N_2O_3. To perform the estimation, take 100 cc of the sample water, add to it 1 cc of the sulphuric acid solution and 1 cc of the metaphenylene-diamine solution, mix and set aside. Now prepare with distilled water standards, containing 0·5, 1·0, 1·5, and 2·0 cc of standard sodium nitrite solution and add the same amounts of the solutions 1 and 2 as were added to the sample, compare the colours, and if the sample matches one of them the calculation is simple and obvious, since we know that 1 cc = 0·01 milligramme of $N\ O_3$

if it matches the one containing 0·5 cc, the water contains 0·005 part per 100,000 of N_2O_3; or if for example it matches the 2·0 cc one, then 0·02 part per 100,000; if it is darker than any of these, an aliquot part of the 100 cc should be taken, say 10 cc, 20 cc, 25 cc, or 50 cc, and the amount of colour in this amount compared with the standards as described when speaking of the colorimetric method and using Stokes' colorimeter. For example, let us say that 10 cc, *i.e.,* one tenth of the original 100 cc to which were added 1 cc of each of the reagents (acid and metaphenylene-diamine), matches the 1·5 cc solution, in which case if 10 matches 1·5, 100 will match 15·0, *i.e.,* the water contains 15 × ·01 milligramme N_2O_3, or 0·15 part per 100·000.

Another mode of estimating nitrites is the method known as Ilosvay's, which depends for its action on the fact that if we add a solution of sulphanilic acid $C_6H_4(NH_2)SO_3H$ (obtained by heating aniline with fuming sulphuric acid) to a water containing nitrites, diazo-benzene-sulphonic acid $C_6H_4\left(\begin{smallmatrix}N=N\\SO_3\end{smallmatrix}\right)$ is formed, and this, on the addition of a solution of alpha-naphthylamine $C_{10}H_7NH_2$, forms a pink colour.

The test is performed as follows:—

In 100 cc of distilled water place 1 cc of the standard sodium nitrite solution, call this A; take 100 cc of sample water, call this B; to both A and B add 2 cc of the sulphanilic acid and 2 cc of alpha-naphthylamine solutions, after five minutes compare A and B; the colours are then equalised by diluting one or the other and taking a careful note of the degree of dilution, and the calculation performed, as in other similar cases.

Example: A is lighter than B, and B has to be diluted to $\frac{1}{4}$, *i.e.,* 25 cc of B when made up to 100 cc, give a colour matching that of B, ∴ B contains four times as much N_2O_3 as A, but A contains 0·01 milligramme of N_2O_3, ∵ B contains 0·04 milligramme N_2O_3, *i.e.,* 0·04 part per 100,000 of N_2O_3.

Oxidisable Matter in water may be organic or inorganic, the organic being sub-divided into animal and vegetable. In order to form an estimate of the amount of oxidisable organic matter in water, advantage has been taken of the fact that potassium permanganate is capable under certain circumstances of parting with its oxygen to this organic matter, the circumstances most favourable being an acid medium and a certain degree of warmth. Forchammer devised a process which Tidy improved upon, and this is the process generally adopted for estimating oxidisable matter. In regard to the acid, diluted sulphuric acid is the best to employ, other acids would interfere with its action, more or less; take for example the case of hydrochloric acid, if hydrochloric acid is too concentrated, or too warm, it becomes decomposed, and free chlorine is given off, which acts as a reducing agent upon the permanganate this would render it impossible to get even an approximate estimate of the organic matter present. Dilute sulphuric acid on the other hand has no such defect and it also prevents the formation of hydrated maganese dioxide, and holds maganous oxide in solution. The substances which permanganate has no effect on, are, amongst others, sugar, gelatine, urea, and creatin; permanganate is reduced by iron, sulphides, and nitrites, but these, if present in a water, would be readily detected by the qualitative tests, and any oxygen given up to them could be allowed for.

Vegetable organic matter, which is of course of vastly less importance than animal organic matter, is much more readily oxidised, and this is the principal argument against the use of potassium permanganate for the determination of oxidisable matter in water, but on the other hand the estimation by permanganate when carefully performed is of great value as giving an estimate of the purity of the water which is valuable for purposes of comparison, since, apart from the cases of upland surface water containing much peat, the amount of oxygen absorbed by waters of undoubted purity varies within very narrow limits; speaking generally, a good water should not require more than 0·285 to 0·357 part per 100,000 of oxygen to oxidise the organic matter present, and, as a general rule, a good water will not require more than half these amounts.

Detail of the *Tidy-Forchammer* process:—

Requirements. Two 12-oz. stoppered bottles made of clear white glass; a burette graduated to $\frac{1}{10}$ cc; and two 1 cc pipettes.

Reagents:—

(1). Standard solution of potassium permanganate, 1 cc of which contains 0·0001 gramme, *i.e.*, 0·1 milligramme of available oxygen, this solution is made by dissolving 0·395 gramme of potassium permanganate in a litre of distilled water.

(2). Dilute sulphuric acid made by taking 1 volume of pure sulphuric acid, diluting it with 3 volumes of pure distilled water, and dropping in potassium permanganate solution until a permanent pink colour persists after the acid solution has been warmed to 80° F. for four hours.

(3). A solution of potassium iodide (1 in 10 of water) free from iodate, best obtained by recrystallisation from a solution in alcohol.

(4). Sodium thiosulphate (*i.e.*, sodium hyposulphite) solution, 1 part of the "hypo" in 1000 of distilled water.

(5). Starch solution (for use as an indicator), one part of starch rubbed up with 500 parts of water, then boiled for five minutes and allowed to cool, and, if necessary, filtered.

The process is conducted as follows :—

Take 250 cc of distilled water, place it in a bottle marked A, and also 250 cc of the sample water, and place it in a bottle marked B.

Warm A and B to a temperature of 26·7° C. (80° F.), then add to each 10 cc of the sulphuric acid solution and 10 cc of the permanganate solution, set aside in a warm cupboard or warm place where the temperature will remain constant at 80° F. The test should be done after the above treatment for 15 minutes, and another set similarly treated for four hours, in both cases, whether for 15 minutes or 4 hours, the method of titration is the same, and is as follows :—Into A and B run a few drops of the potassium iodide solution, sufficient to destroy the red colour ; then into each in turn first run sufficient hyposulphite solution to *nearly,* but not quite, destroy the yellow colour due to the presence of free iodine liberated by the O_2 of the permanganate, then add a drop or two of starch solution ; a bright blue colour due to iodide of starch should now be seen ; after this more hyposulphite of soda is run in from the burette until the blue colour just goes, so that if we now add one drop of the permanganate solution the blue colour returns. Read off the total number of cc of "hypo" used for A, and repeat the process in an exactly similar manner with B, and note the number of cc used for it. In the case of very impure waters, or certain waters like upland surface water containing peat, 10 cc of permanganate solution may be insufficient to give the water a pink colour which will last 15 minutes or four hours as the case may be, then it will be necessary to add more permanganate solution, and the amount so added in addition to the 10 cc must be carefully noted, and a like amount added to to the blank experiment with distilled water.

The calculation is made in the same way whether the process has lasted 15 minutes or 4 hours, or whether 10 cc or more of permanganate have been added ; in general terms the calculation may be expressed thus :—

$$\frac{A - B}{A} \times n \times 0{\cdot}1 \times 0{\cdot}4 = \text{answer in parts per 100,000.}$$

In this case A = the number of cc "hypo" used with 250 cc distilled in the control or blank experiment. B = the number of cc "hypo" used with 250 cc of the sample water. n = the number of cc of permanganate solution added to the water, and this is multiplied by 0·1, because each 1 cc $K_2 Mn_2 O_8$ solution contains 0·1 milligramme of available oxygen, and this is multiplied again by 0·4 in order to bring the result to parts per 100,000 (0·4 being the same as $\frac{2}{5}$); two-fifths of the amount found is taken because we took 250 cc of water and we require our results in milligrammes per 100 cc, because 250 : 100 :: 5 : 2.

For purposes of illustration let us take an actual example :—

250 cc of distilled water + 10 cc $K_2 Mn_2 O_8$ solution required 30 cc of "hypo" to combine with the iodine set free from the iodide of potassium by the available oxygen in 10 cc of $K_2 Mn_2 O_8$ solution; in the case of distilled water where there is no oxidisable matter present, the available oxygen would be 1·0 milligramme, so the amount of "hypo" used corresponds in this case, to 1 milligramme of oxygen. 250 cc of the sample water + 10 cc $K_2 Mn_2 O_8$ required 25 cc of "hypo" to combine with the iodine set free from *what remained* of the available oxygen after a certain amount x of oxygen had been parted with to oxidisable matter present in the water.

Then 30 — 25 which = 5 is the amount of oxygen parted with to organic matter in the 250 cc water in terms of "hypo," now it was found by the blank experiment A that 30 cc "hypo" are equivalent to 10 cc $K_2 Mn_2 O_8$ solution, *i.e.*, to 1 milligramme of oxygen. ∴ 5cc = $\frac{5}{30}$ of 1 milligramme O_2, *i.e.*, $0\cdot1\dot{6}\dot{6}$ milligramme, and so ·166 × 0·4 = 0·0664 milligramme per 100 cc, or 0·0664 part per 100,000.

The reactions which occur during the various stages of this process are represented by the following chemical equations :—

1st stage :—

$$K_2 Mn_2 O_8 + 6 H_2 SO_4 = 4 MnSO_4 + 2 K_2 SO_4 + 6 H_2 O + 5 O_2$$

Potassium permanganate and sulphuric acid form sulphates of manganese and potassium. and water, whilst oxygen is set free to combine with any oxidisable matter with which it comes in contact.

2nd stage :—

Any oxygen remaining over and above that given up to organic matter is available for the liberation of iodine from iodide of potassium added in the second stage, thus :—

$$K_2 Mn_2 O_8 + 8 H_2 SO_4 + 10 KI = 6 K_2 SO_4 + 2 MnSO_4 + 8 H_2 O + 5 I_2$$

In the third stage the amount of sodium thiosulphate solution ("hypo") required depends upon the amount of iodine which has been liberated thus:—

$$2 Na_2 SO_3 + I_2 = 2 NaI + Na_2 S_4 O_6$$

Sodium thiosulphate and Iodine form sodium iodide (colourless) and sodium tetra-thionate.

Lead in Water.—Lead is a cumulative poison, and by reason of the small amounts of lead which are usually met with in drinking water, it is possible by prolonged use of a lead-contaminated water to at length reach a very severe stage of plumbism without the suspicions of the patient, or even the medical man, being at all aroused. There have been several severe outbreaks of lead-poisoning on an extensive scale where a plumbo-solvent water has been conveyed in leaden pipes, without the nature of the sickness being recognised until the analyst has detected lead, and then at once many cases of obscure sickness have become readily explained, and many well-known symptoms of plumbism, previously overlooked, have been observed. Palor, extreme debility, depression of spirits, mental derangements, dyspepsia, colic, and constipation are usually seen; but Bright's disease, gout, defective vision, and even blindness may occur after prolonged lead poisoning. It is most important then to understand the circumstances under which we are likely to find lead in a water supply, and, also to know how lead can be eliminated from, or better still, prevented from getting into a water-supply.

Soft waters are those in which lead is usually found, but soft water requires either a certain amount of aëration due to dissolved oxygen or carbonic acid gas, or else a certain degree of acidity, and in addition certain salts such as nitrates and chlorides aid the solution of lead, this is particularly the case with ammonium salts; the presence of decaying vegetable matter, especially peat, also favours this action.

Oxygen in water acts by forming the hydrated monoxide $Pb (HO)_2$ when it comes in contact with metallic lead; carbonic acid acts by rendering the otherwise insoluble $PbCO_3$ slightly soluble. Peaty waters owe their plumbo-solvent action to acidity, which is the result of bacterial growth. Two acidifying bacilli, named "P" and "Q" bacilli, have been isolated from peaty earth, and proved by experiment to be the offenders. Peaty water which has soaked into the soil and issued elsewhere at a spring exerts little or no plumbo-solvent action, because the bacilli have been removed by the filtration and the acidity neutralised by the alkaline bases of the soil; peaty water on the other hand which has run directly out of a peat bog into a reservoir or into pipes has a remarkable power of dissolving lead. Houston was able to show that bacilli caused the water to become acid in the following way: he took some upland surface water, showing no plumbo-solvent power, then added to it a sterile decoction of peat, the water still showed no plumbo-solvent action, but when to this water he added a small amount of living peat earth, the water was quickly acidified. Waters containing the alkaline carbonates, such as calcium or magnesium carbonate, will not take up lead, since white lead, a mixture of lead carbonate and lead hydroxide $Pb\ (CO_3)_2\ Pb\ (OH)_2$ is formed, this is an insoluble substance, which, being deposited on the metal, protects it from further change; likewise waters containing sulphates will not give rise to lead poisoning since lead sulphate ($PbSO_4$) is a very insoluble salt, and this is deposited on the pipes, and prevents further action.*

One method of removing lead from a water-supply on a large scale consists in adding calcium carbonate to the water (3 grains to the gallon); another is to filter the water through some lime-containing medium, such as limestone, in addition to the ordinary medium employed by water companies for filtering on a large scale. For domestic purposes, an animal-charcoal filter will efficiently remove lead by forming insoluble lead phosphate.

Quantitative estimation of lead requires :—

Apparatus—(1) burette graduated to $\frac{1}{10}$ cc; (2) Nessler glasses, 50 cc capacity, with mark at 50 cc; (3) pipettes to hold 5 cc and 1 cc respectively.

Reagents—(1) pure distilled water; (2) dilute hydrochloric acid; (3) sulphuretted hydrogen solution; (4) standard solution of lead, 1 cc of which = 1 milligramme of Pb, this is made by dissolving 1·575 gramme $Pb\ (C_2H_3O_2)_2$ in a litre of distilled water, because 354·27 parts of $Pb\ (C_2H_3O_2)_2$ (lead acetate) contain 205·35 parts of Pb (lead) therefore the amount of lead acetate equivalent to 1 part of lead is $\frac{354 \cdot 27}{205 \cdot 35} = 1 \cdot 575$.

Detail: add to 50 cc of the sample water 1 cc of dilute hydrochloric acid and 5 cc of sulphuretted hydrogen solution,

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* Water containing 17·5 grains per gallon of Calcium Sulphate will only dissolve ·05 grain of lead per gallon in 72 hours, but water containing 1·4 grain per gallon of Ammonium Nitrate will dissolve 1·75 grain per gallon in the same period.

and add the same quantity of reagents to standards prepared containing various known amounts of lead; with small amounts of lead greater accuracy is possible than with larger amounts, and since, as a rule, a water only contains minute amounts of lead, this method is sufficiently accurate for an ordinary hygienic analysis.

Example: 50 cc of the water and reagents as noted matches standard containing 0·5 cc of standard lead solution, *i.e.,* 50 cc contains 0·5 milligramme of lead, and 100 cc contains 1 milligramme of lead, *i.e.,* 1 part per 100,000 or 0·7 grain per gallon.

House Refuse an indication of pollution.—If there be any sediment, it is collected by allowing the sample of water to stand some hours in a cylinder—a glass having a conical bottom with rounded apex pointing downwards—a portion of it is removed with a pipette, and a drop placed on a slide and examined with an inch or ¼-inch objective. There are certain substances which are sure to find their way into water if either sewage or house refuse—which includes slop-water and refuse from scullery sinks—gain access to the water supply. These substances we have already enumerated, it remains to describe those most commonly found.

Cotton may be met with as woven threads, when the unaided eye would recognise them, or small portions of cotton fibre, such as become detached from calico cloths, etc., may be found by the microscope, when they appear as thin taper-like bands twisted on themselves; these are readily stained by any of the basic aniline dyes, such as gentian or methyl violet; they are not dissolved nor stained yellow by nitric acid, but when in contact with it, they become untwisted. *Fig.* 33 (*a*).

Wool. The fibres of wool are seen even under a 1-inch objective to consist of rounded fibres with peculiar irregular imbrications; in old wool fibres which have been frequently washed, these markings are often indistinct, but can generally be made out; they stain readily, and are turned yellow by nitric acid. *Fig.* 33 (*c*).

Silk fibres are structureless hyaline rods, in which occasional nodes are sometimes seen, when acted on by dilute mineral acids they first become indistinct, and then dissolved, they stain readily with any dyes, but especially well with picric acid. *Fig.* 33 (*d*).

Linen fibres are cylindrical, and show transverse markings at intervals, these are not always very clear, but small fibres are almost invariably seen coming off at various points, resembling the adventitious roots of certain creepers. *Fig.* 33 (*b*).

Hair shows a cortical and medullary substance; light hair shows this less markedly than dark hair; nearly all hair shows imbrications more or less; in the hair of rabbits and cats, and in that of some human subjects, these are well marked. *Fig 33* (*e*).

Epithelial cells and muscle fibres need no description.

Spiral vegetable cells, such as pieces of undigested cabbage, are also easily recognised.

Fig. 33.

a. Cotton. *b*. Linen. *c*. Wool. *d*. Silk. *e*. Hair.

Starch cells. These consist of two substances, starch-cellulose and granulose, the latter staining blue with iodine, whilst the former is turned brown; the characteristic appearance of the various starches is detailed in another chapter (*vide* pp. 168—175).

Bacteriological Examination. When possible a bacteriological examination should always be made, but unless done with great care it is of little value; there is no doubt that if one had to choose between two examinations of water, viz., a chemical and biological one, that in the great majority of cases a chemical analysis, carefully performed, would afford the more reliable information as to the purity of a water; a chemical analysis will nearly always warn us of danger, but will, unfortunately, sometimes afford a feeling of false security: a bacteriological examination in many cases will fail to detect dangerous pathogenic microbes even after a prolonged and careful investigation, as, unfortunately, has been seen in several severe epidemics of typhoid fever. The general nature of the means employed for detecting pathogenic micro-organisms is here given:—

Firstly, the water must be collected with care, if possible in sterile vessels, if it is not possible to have absolutely sterile vessels, at any rate let them be free from any suspicion of being infected by pathogenic organisms.

Secondly, since micro-organisms multiply exceedingly rapidly if the temperature be at all warm, the water should be examined at once, or the sample kept at as low a temperature as possible until the examination can be made.

Thirdly, it is assumed that a number of sterile test-tubes, sterile Petri's dishes, and the various apparatus connected with a bacteriological laboratory are available, also a supply of culture media, such as nutrient gelatine, agar-agar, and beef bouillon. We therefore proceed to describe the process for enumerating the micro-organisms in a sample of water, and separating, by means of plate cultures, suspicious colonies.

Having sterilised a 1 cc pipette, it is filled up to the mark with the sample water, and one, two, or at the most four drops of the water are allowed to fall into a tube of liquefied gelatine, the temperature of which feels warm but not hot when held in the hand (about 40° C.), this is rolled and agitated gently in order to ensure thorough mixing, and then poured out on to a small sterile glass plate, placed upon another sterile glass plate with a sterile cover, this is supported by a dish filled with ice and water, which rests upon a carefully adjusted levelling apparatus. If the plate has been carefully levelled the liquefied gelatine will readily flow in an even manner over the plate, but if not level it will overflow, and all the material and trouble will be wasted. Petri dishes, 10 cm. in diameter and 1·8 cm. deep, are more convenient and answer the purpose equally as well as, or even better than, the glass plates, these should be allowed to set on a levelling stand over ice, in order to ensure an even distribution of the gelatine and a speedy solidification. The plates or dishes are, when set, placed in a sterile glass chamber in a cool situation, where the temperature will not exceed 22° C. Gayon's flasks are frequently used in lieu of the glass plates or Petri dishes, these are figured in various catalogues.

After two or three days colonies will appear, every colony representing one parent microbe, so that by counting the colonies over a microbe counter (which can be improvised by the worker, or he can employ Wolfhügel's, in which a glass plate 12 cm. square is sub-divided into squares of 1 cm., and some of these are again sub-divided into 9 smaller squares) we find the number of microbes contained in the quantity of water taken, and these are counted and noted from day to day until liquefaction has occurred, and any peculiarities of growth noted. In regard to the amount of water taken it is important to know what fraction of a cc was taken: this is found by seeing experimentally how many drops are delivered per cc by the pipette used, and then we note on the culture the name of sample, date, medium, the number of drops used as a fraction in which the denominator is the total number of drops per cc which the pipette delivers; a convenient method is to use a pipette made to give a definite number of drops, or if the water be one likely to contain many microbes, take say 1 cc of the sample and add this to a sterile test-tube containing 9 cc of sterile water, we shall then have a 1 : 10 solution of the water; if now we take $\frac{1}{10}$ of 1 cc of this water and introduce it by means of a drop-counter into a tube of nutrient gelatine, we shall be working with $\frac{1}{100}$* cc of the original water, and the number of microbes found in the plate culture multiplied by 100 will be the number per cc. Now-a-days plate cultures are made more with a view to isolating special species than to enumerating the microbes. Miquel, however, has laid down a scale of purity based upon the number of micro-organisms *found at the time of collection*, thus:—

0 to 10 germs per cc show a water to be excessively pure.
10 to 100 germs per cc show a water to be very pure.
100 to 1000 germs per cc show a water to be pure.
1000 to 10,000 germs per cc show a water to be of medium purity.
10,000 to 100,000 germs per cc show a water to be impure.
More than 10,000 germs per cc show a water to be very impure.

A larger number of micro-organisms in a water shows either that surface washings or sewage are gaining excess to the water-supply. A deep well should show very few micro-organisms.

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* A further dilution might be made with advantage in the cases of very polluted waters.

The chief pathogenic organisms known to be spread by water are those of cholera and typhoid fever. Cholera is readily detected. Metchinkoff's method is that in which 200 cc of the water are taken and placed in a sterile flask capable of holding a little over 250 cc, and then the following solution is added, after being previously sterilised, it consists of 2 grammes best peptone, 2 grammes sodium chloride, 4 grammes gelatine, and sufficient solution of sodium carbonate to render the solution slightly, but nevertheless clearly alkaline, and then distilled water is added to make it up to 50 cc.

The sample, after this solution has been added, is incubated at 37° C., at the end of eight or ten hours a distinct pellicle will form on the surface if the vibrio of Asiatic cholera is present, from this, gelatine stab cultures should be made, when the growth which occurs is characteristic; after 24 hours liquefaction is seen to be commencing all along the needle track, and at the point of entrance the liquefaction is rather more marked and encloses a bubble of air; in a gelatine culture of Finkler-Prior's vibrio the needle track is more funnel-shaped at this period, which distinguishes it from the vibrio of Asiatic cholera. The microscopic appearance of the vibrio of Asiatic cholera is well-known, comma-shaped curved rods, 1·5 to 3 μ long and 0·5 to 0·6 μ broad; which stain well with Ziehl-Neelsen fuchsine diluted three or four times with water, or with a weak watery solution of methyl-violet, but they are not stained by Gram's method. The grouping of the bacilli is another distinguishing feature; in each collection of bacilli the individual bacilli point the same way.

The vibrio of cholera gives the indol reaction, or cholera-red. If the culture contained nitrates, these are reduced to nitrites by the cholera vibrio, and on the addition of a drop of strong sulphuric acid a red colour is produced, or it may be obtained by adding to a broth culture tube containing the vibrio of cholera the following substances:—First, 1 cc of a solution of potassium nitrite 0·02 per cent. strength, and then slowly 1 cc of pure H_2SO_4 diluted with three parts of water; if the culture contains indol a rose-colour is seen.

The bacillus of typhoid fever usually gains access to a water-supply through defective drainage, and the detection of it is often a matter of very considerable difficulty, even in the case of sewer effluents known to be contaminated by typhoid excreta it has not always been found even after a prolonged and careful examination. The difficulty in isolating the bacillus may possibly be due to the fact that typhoid fever bacilli are only met with in the stools of typhoid patients when Peyer's patches are ulcerated, that is to say about the middle of the second week of the disease, and according to Besson it is only met with in the urine of patients suffering from typhoid fever when the urine is albuminous, for as soon as this ceases to contain albumen the bacilli disappear. Besson found it in 40 per cent. of typhoid cases where the urine contained 0·1 per cent. and upwards of albumen.*

Various methods have been devised, such as incubating some of the suspected water (20 to 100 cc) with sterile beef broth at a temperature of 45° C.; at 45° C. most micro-organisms cease to multiply, whereas the bacillus coli and Eberth's typhoid bacillus will; if then the broth becomes turbid in from 20 to 24 hours these micro-organisms are suspected and plate cultivations should be made, preferably with nutrient gelatine to which carbolic acid has been added in sufficient extent to amount to 0·002 per cent., this small amount of phenol restrains the growth of liquefying organisms and enables one to pick out colonies of the typhoid fever bacillus and those of the bacillus coli.

Parietti's method for isolating typhoid fever bacilli consists in adding from 3 to 9 drops of the following solution to 10 cc of sterile broth or liquefied nutrient gelatine:—Carbolic acid, 5 grammes; hydrochloric acid, 4 grammes; distilled water, 100 grammes. If broth be employed, this should be incubated at 41° C., if gelatine, at 20° C. to 22° C.

Elsner's medium is now usually employed for cultivations with suspected water, upon it the bacillus coli and Eberth's bacillus grow freely, and can be picked off and planted out, it is, according to Besson,* prepared as follows:—

(1). 500 grammes of potato are peeled and grated.

(2). The pulp thus obtained is macerated in a litre of water for three or four hours.

(3). It is then strained, left for one night, and decanted.

(4). The volume is made up to 1000 cc, and 150 to 200 grammes of gelatine are dissolved in it with the aid of gentle heat; when dissolved it is boiled for some minutes.

(5). The liquid is very acid, this acidity is therefore reduced by the addition of a little sodium carbonate solution, so that it shall still be acid, but only to a slight extent.

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* The presence of typhoid fever bacilli in the urine of sufferers from typhoid fever, has lately been thought to be due to stray bacilli becoming lodged in the folds of the mucous membrane of the bladder; it is assumed that these bacilli are brought in the blood to the kidneys and from there conveyed to the bladder in the urine, where, under favourable conditions, they rapidly multiply and get washed away from time to time during micturition.

(6). Heated to 115° C. for five minutes, and filtered warm.

(7). Returned to the flask and sterilised at a temperature between 112 and 115° C.

A series of test tubes containing 19 cc of the above medium are sterilised in an autoclave, and also the following solution, consisting of 10 grammes of potassium iodide in 50 grammes of distilled water. When required for use, to each tube of potato-gelatine, liquefied at a gentle heat, is added 1 cc (20 drops) of the iodide solution, in this way we obtain a gelatine containing 1 per cent. of iodide.

To each of the tubes thus prepared is added some drops of the suspected water, then the contents of the tubes are poured into Petri dishes and allowed to set; six or eight plates ought always to be prepared, which are incubated at 20° C.

Opaque rounded colonies of the bacillus coli appear on the second day, whereas typhoid bacillus colonies only appear on the fourth day, and are then transparent, and scarcely visible; according to Elsner, colonies of other bacteria are not noticeable at this time, but as a matter of fact colonies of other bacteria are present, and the colonies of bacillus coli and bacillus typhosus are by no means so distinct; the great advantage of Elsner's medium in the words of Besson lies not in any specific power which permits the growth of bacillus coli and bacillus typhosus and excludes others, but only in the fact that bacillus coli and bacillus typhosus can grow side by side.

To differentiate between the bacillus coli and typhoid bacillus:—

Method of culture.	Bacillus coli.	Typhoid bacillus.
(1). Grown in beef broth at 38·5°C., containing lactose carbonate.	Numerous bubbles of gas, set free in from 12 to 36 hours.	No gas set free.
(2). Gelatine shake cultures grown at 22°C.	After 24 hours, copious gas formation.	No gas formation.
(3). Culture in sterile milk.	Acidified and coagulated in 24 to 36 hours.	Acidified but not coagulated.
(4). Broth culture.	Shows indol reaction.	No indol reaction.
(5). Grown on potato.	Thick brownish growth.	Culture transparent and thin.

*Page 40. Technique Microbiologique Baillière et Fils, 1898.

In cases where there is reason to believe that typhoid fever is attributable to the use of water sent for analysis, and the previous methods have failed to detect the bacillus typhosus, it would be well to filter a litre of the water under examination through a Pasteur-Chamberland or Berkefeld filter.

It is necessary that the candle of the filter employed should be sterile, this having been assured, the water is caused to flow through one of the filters, this is done by connecting the nozzle of the filter with an air-tight flask capable of being connected with an air-pump; when the water has passed through the filter it will be sterile, and all the micro-organisms contained in the quantity of water taken will be deposited on the outside of the filter, pour 10 cc of the filtered water, which is now sterile water, into a sterile beaker capable of being plugged with sterile cotton wool, and, "with a soft sterilised tooth-brush, gently scrape the candle of the filter, so as to get as many as possible of the bacteria from the surface of the candle into the beaker."* The beaker is once more plugged, and now contains a concentrated solution of bacteria; a large series of phenolated gelatine tubes, previously prepared, are melted, and one or two drops of the solution of bacteria are added to each tube and plate cultures set. Sub-cultures are made if any colonies appear in these carbolised plates, and the presence or absence of typhoid fever bacillus is determined by microscopical examination, and the various tests performed by which differentiation between coli and typhoid bacilli is arrived at. In the microscopical examination typhoid fever bacilli if stained for by Van Ermengen's silver method show numerous flagellæ, a single bacillus will often show as many as 17 or 18 long wavy flagellæ, when stained by this method. Coli bacilli show very few, and these are shorter.

Typhoid bacilli are straight and slightly curved rods with rounded ends, some appear to be oval. Coli bacilli are plump straight rods with rounded ends, and less motile than the typhoid bacilli.

Both kinds stain well with the basic aniline dyes, but do not stain with Gram's method.

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* Practical Bacteriology by Kanthack and Drysdale.

CHAPTER V.

METRIC SYSTEM OF WEIGHTS AND MEASURES.

The metric system of weights and measures is universally employed in all laboratories, notwithstanding that in water, and other analytical reports, results are often expressed in grains per gallon, grains per lb., etc. The meter was adopted as the unit of length, and thought to be the one ten millionth part of the distance from the equator to the pole; this has since been found not to be strictly, although very nearly so, but this fact does not detract from its value as a unit of length. The fractions of the meter are termed deci-, centi-, and millimeters; and the multiples, deca-, hecto-, kilo-, and myriameters; it will be seen that the first series are given *Latin* and the second *Greek* prefixes.

If we remember that a meter is 39·37079 English inches, we can without difficulty remember the factor to divide or multiply by, when converting the meter measures into English inches, or English inches into meters or its fractions or multiples. For example: if it is required to know how many millimeters are equivalent to 30 inches, divide 30 inches by 0·03937, or multiply 30 inches by 25·4, and the result is found to be 762; or again it is required to find how many inches are equal to 60 centimeters, multiply 60 by 0·3937 or divide 60 by 2.54, and the result—23·622 inches.

The unit of weight is the weight of a cubic-centimeter of pure distilled water weighed at 4°C, the temperature of the maximum density of water, and this weight is called a gram, and in a similar manner, as with the unit of length, the fractions are called deci-, centi-, and milligrammes, and the multiples deca-, hecto-, and kilogrammes; and it follows, that a decigramme of pure water at 4°C occupies the tenth of a cubic centimeter, a decagramme of pure water at 4°C occupies 10 cubic centimeters, and so on. 1000 cubic centimeters of water or fluids are generally spoken of as a litre.

The weight of a gram in English avoirdupois weight is 15·43235 grains, but it is generally sufficient to remember the weight to three places of decimals, and then we have the weight of a gram as being equivalent to 15·432 grains, a number which, from the sequence of the figures, cannot be forgotten.

In using a chemical balance, there are certain points to be observed. The substance to be weighed is put in the left scale pan because we can place the rider on various points on the right beam without opening the case, as most balances are made for right handed people. The substance to be weighed must be cool, if warm, currents of air are set up which cause the scale pan to oscillate, and so lead to error. The balance must be brought to rest before adding or removing weights, the beam must be poised on the knife edge with the greatest possible care, the windows of the balance should be closed at the time of the final weighing, and the air of the cabinet which encloses the balance must be kept dry by means of a beaker containing some hygroscopic substance, such as calcium chloride or pure sulphuric acid.

Specific gravity is the weight of a substance compared with the weight of an equal bulk of something else. As a rule, the term specific gravity refers to the weight of a substance compared with that of an equal bulk of water, or in other words, its specific gravity is its weight in air divided by the loss of weight in water.

The specific gravity of fluids is found either by employing a specific gravity bottle of known weight, capable of holding a known weight of water at a certain temperature (15·5°C). The bottle is fitted with a glass stopper and a counterpoise indicating the weight of the bottle is supplied with it. To find the specific gravity of the fluid, the bottle is filled at the given temperature (15·5°C), and the weight thus found is divided by the weight of water which the bottle holds. For example: a bottle which holds 100 grammes of water, when filled with oil holds 91·5 grammes of oil, so $\frac{91 \cdot 5}{100} = 0 \cdot 915$, which is the specific gravity of the oil.

Another method employed is to use an instrument called a hydrometer, graduated so as to show the specific gravity of the liquid directly, the specific gravity being marked on the stem in the matter familiar to all. A third method employed in the case of fluids shows the weight of the fluid displaced by means of a plummet suspended from a graduated beam, by noting the weight required to sink it to a certain mark which is indicated by riders of different sizes, each size being exactly one-tenth the weight of the next size larger. Westphal's balance acts in this way and is a miniature "steel-yard" modified so that the beam is not suspended, but balances on an agate knife edge, the plummet used with it contains a sensitive thermometer and exactly displaces five grammes of distilled water at 15° C.

The plummet weighs 15 grammes in air, but only ten grammes in water because, as we have just said, it displaces five grammes (5 cc) of water, in order then to restore the level of the balance if the fluid in which it is suspended is water, or of the same density as water, a five gramme rider is fastened to the end of the beam which supports the plummet, and the balance is now seen to rest horizontally if the fluid in which it is suspended is heavier than water; then, in addition, we shall have to put on more weights, and in the case of fluids lighter than water, less than five grammes will be sufficient, as explained further. The riders are of four sizes—5 grammes, 0·5 gr., 0·05 gr., and 0·005 gr., and the beam of the balance is divided into tenths, and riders are placed on the notches at these divisions until a perfect balance is attained. If a balance can only be attained by two or more of the riders being on the same division, these are suspended one from the other, the larger ones supporting the smaller ones.

Fig. 34. WESTPHAL'S BALANCE.

To make this clear let us take the case of a sample of milk having a specific gravity of 1·029. In this case the five gramme rider, or No. 1 size, will hang from the end of the beam as it does when immersing the plummet in water; the second size rider will hang from the No. 2 division of the beam, and the third size from the No. 9 division. That is to say, the plummet which in water displaces five grammes, in milk displaces 5 grammes 1 decigramme, 4 centigrammes, and 5 milligrammes, because a rider which weighs 5 grammes at the end of the beam will only weigh 0·9 × 5 at the 9th division, 0·8 × 5 at the 8th, and so on. Similarly, the 0·5 gr. will at the second division weigh 0·2 × 0·5 grm. = 0·1 grm., and the 0·05 grm. at the 9th division will weigh 0·045 gm., the amount of fluid (in this case milk) displaced, will weigh 5·145 grms., and this divided by an equal bulk of water weighing 5 grammes $= \frac{5{\cdot}145}{5{\cdot}0} = 1{\cdot}029$.

In practice it is only necessary to read off the sizes and positions of the various riders, for we know that in using the balance we can read the specific gravity straight direct, since the first size at any division gives the first place of decimals of the value corresponding to the number of the division and whole numbers only when suspended from the end which supports the balance, the second size means the second place of decimals at any of the divisions, of the value of the number of the division, and so on.

Thus, if using the balance the plummet sinks to the knot on the wire suspending it and the balance is horizontal, with the first size rider at the end of the balance, and the beam supports 2, 3, and 4, all hanging from the third notch, then the specific gravity will be 1·0333 if they had been placed—the 1st size at the end, the 2nd size on the 4th notch, the 3rd size on the 2nd notch, and the 4th size on the 9th notch, then the specific gravity would have been 1·0429.

If the specific gravity is less than that of water—say 0·896—then the No. 1 size must be placed on one of the *divisions* (in this case the 8th), the 2nd size rider would be on the 9th division, and the 3rd size on the 6th.

The plummet which lost 5 grammes weight in water in this fluid only lost

$$\begin{aligned} 0{\cdot}8 \times 5 &= 4{\cdot}0 \\ 0{\cdot}9 \times {\cdot}5 &= {\cdot}45 \\ 0{\cdot}6 \times {\cdot}05 &= {\cdot}03 \end{aligned}$$

$\frac{4{\cdot}48}{5{\cdot}0} = 0{\cdot}896$ = the specific gravity of the fluid in question.

For fluids considerably heavier than water, specific gravity is generally taken with Beaumé's hydrometer, or areometer, and the density expressed in degrees of Beaumé.

Thus 0° Beaumé = sp. gr. 1·000
1° ,, = ,, 1·007
2° ,, = ,, 1·014
3° ,, = ,, 1·020
4° ,, = ,, 1·028
5° ,, = ,, 1·034

Beaumé's hydrometers are constructed so as to show the density of fluid up to a specific gravity of 1·960, *i.e.* 72° Beaumé's scale, and for light liquids, as low a specific gravity 0·706.

CHAPTER VI.

EXAMINATION OF AIR.

COMPOSITION OF AIR.

Pure Country.

	Vols. per cent.
Oxygen	20·9 to 20·99
Carbonic Acid	0·03 to 0·04
Nitrogen	79·0

(1 per cent. of what was hitherto regarded as N_2 is now attributed to argon.)

Aqueous vapour	0·4 to 1·6 (*According to temperature*)
Ammonia	Traces
Ozone	,,
Mineral substances	,,
Organic matter	,,
Marsh gas	,,

Air of Towns.

	Vols. per cent.
Oxygen	20·86 to 20·92
Carbonic Acid	0·04 to 0·05
Nitrogen	79·0
Aqueous vapour	0·4 to 1·6 (*According to temperature*)
Ammonia	Traces
Sulphur Dioxide	,,
Oxidised Nitrogen	,,
Marsh gas	,,
Organic matter	Heavier traces than are met with in pure country air.
Carbon particles as soot	

Respired Air.

	Vols. per cent.
Oxygen	16·033
Nitrogen	79·557
Carbonic Acid	4·38
Ammonia	Traces
Hydrogen	,,
Methyl Hydride	,,

Aqueous vapour nearly to saturation.

The object of an examination of air for sanitary purposes is to find out the nature of impurities and the extent to which they may be present. Impurities may be said broadly to be introduced in three ways:—(1) Result of respiration; (2) combustion; (3) trade processes.

It has been said that many of these impurities are present to such a small extent that it would appear at first sight trivial to devote so much attention to them, the classic example which illustrates the importance of this attention will bear repeating. Suppose that an impurity of a hurtful nature (such as organic matter from the skin or lungs) be present to the extent of 0·019 per cent.; 0·019 per cent. is the same as 190 parts per million; there are 70,000 grains in a gallon, so that if instead of expressing the impurity in parts per million, we express it in parts per 70,000, we can then think of it in grains per gallon. 190 per million is then seen to be equivalent to 13·3 per 70,000, or in other words 13·3 grains per gallon. Now 13·3 grains per gallon of organic impurity in a water would be considered an appalling amount, and it is improbable that a gallon of water would be drunk by one individual in a day, yet we breathe in daily between 1000 and 2000 gallons of air, and the extent of pollution quoted is often exceeded, so by this example we see very clearly how minute quantities of impurity present in the air, by reason of the large quantity of air breathed, become a grave source of danger. It has been found that the carbonic acid gas given off by respiration affords a valuable index to the extent of vitiation of the atmosphere by respiration, but it must be clearly understood that the carbonic acid (CO_2), the result of respiratory pollution, is very different from CO_2, the result of combustion, and differs to a still greater extent from the $C O_2$, the result of chemical processes, such as occur in the generation of $C O_2$ in the manufacture of aërated waters, etc.; in the former case the oxygen is diminished and replaced by $C O_2$, and at the same time products, which are distinctly harmful, are added. In combustion, if the process is complete, $C O_2$ results, and replaces O_2 in the air, but nothing analogous to the hurtful organic matter given off from the lungs and skin is added. In the third case the $C O_2$ is added to the air and displaces its own volume of air as a whole, 79 per cent. of which is nitrogen, so that even with comparatively large amounts of $C O_2$ thus added, the oxygen is not materially reduced. CO_2, the result of respiration, should never be allowed to exceed 0·02 per cent., *i.e.*, bringing the total amount up to ·06 per cent. or ·6 per 1000, whereas even 1 or 2 per cent. of CO_2 added in the manner indicated in the third case, might be borne without ill-effects.

Examination of the air of a room.

In examining the air of a room much may be learnt by the senses.

If the CO_2, due to respiration, does not exceed 0·2 vols. per 1000, and the moisture is about 4·7 grammes per cubic foot, then the air will appear *fresh*. It is noticed to be *rather close* when CO_2 reaches 0·4 vols. per 1000; *close* when 0·67 is reached; and *very close* when 0·9 per 1000 is reached; at the same time the moisture would probably be about 5·1 grains per cubic foot. In forming an opinion as to whether the air is fresh or otherwise, it is all important that the observer should come into the room under examination fresh from the outside air. If the temperature be high, closeness will be more readily noticed than if it be cold, and if the air be moist it will be even more noticeable; de Chaumont observed that an additional 1 per cent. of moisture was equivalent to an increase in temperature of 4·14° F.; the smell of closeness will also be more noticeable when the air is in motion than when it is still.

The size of the room should be noted, number of occupants, and the available means for ventilation, the temperature of the dry and wet-bulb thermometers, and height of the barometer. Next proceed to collect a sample of the air, this may be done by filling a bottle with the air by means of bellows possessing a nozzle sufficiently long to reach to the bottom of the bottle, the air pumped in, displaces the air which previously filled the bottle; or a simpler and more certain method is to fill the bottle with pure fresh water, empty this out in the room where the air is to be collected, the bottle will then become filled with the air in question. The capacity of the bottle and particulars as to hour of collection, temperature, etc., should always be noted on a label attached.

Estimation of Carbonic Acid Gas.

There are several ways of estimating CO_2 in the air, which depend for their action upon the fact that CO_2 is a weak acid, which, combining with a caustic alkali, diminishes its causticity; by ascertaining the extent to which this diminution of causticity has occurred after exposure to a known volume of air we can then ascertain the amount of CO_2 present.

Pettenkofer's process consists in adding a known volume of baryta or lime water to a known quantity of air, and titrating the baryta or lime water after exposure to air, and also another sample of the same baryta or lime-water which has not been exposed to air, the acid employed being oxalic acid of strength 5·645 grammes to the litre, and the indicator generally used is phenolphthalein, which colours the baryta or lime water red, and remains red until the point of neutralisation is reached, when all the colour goes. 1 cc of this acid solution equals 1 cc of CO_2 gas at 0° C. and 30 inches pressure.

The reason why the solution of oxalic acid is made of this strength (5·645 grammes to the litre) is as follows:—Taking for example the case where baryta water is used, (the exact strength of this is immaterial, but it is usual to employ one containing about 7 grammes of baryta to the litre of water) oxalic acid $H_2 C_2 O_4 + 2 H_2 O$ (90 + 36) combines with barium hydrate, $Ba O H_2 O$ to form a neutral insoluble precipitate of barium oxalate $Ba C_2 O_4 + 2 H_2 O$, likewise carbonic acid gas CO_2 (44) combines with barium hydrate $Ba O H_2 O$ to form neutral barium carbonate $Ba CO_3 + H_2 O$, consequently

$$\underbrace{H_2 C_2 O_4 + 2 H_2 O}_{126} \text{ and } \underbrace{CO_2}_{44} \text{ each equal } Ba O H_2 O$$

$$\therefore \underbrace{H_2 C_2 O_4 + 2 H_2 O}_{126} \text{ is equivalent to } \underbrace{CO_2}_{44}$$

$$\text{and } \tfrac{126}{44} H_2 C_2 O_4 + 2 H_2 O = 1 CO_2.$$

Now the relation between weight and volume of CO_2 is determined as follows:—

The density of a compound gas equals half its molecular weight, therefore since the molecular weight of CO_2 is 44, and $\frac{44}{2}$ grammes occupy the same space as one litre of hydrogen, which weighs 0·0896 grammes, one litre CO_2 will weigh

$$\begin{aligned} 22 \times 0{\cdot}0896 &= 1{\cdot}971 \text{ grammes} \\ \text{and } 1 \text{ cc} &= 0{\cdot}001971 \text{ gramme} \end{aligned}$$

so $\frac{126}{44} \times 0{\cdot}001971$ gramme = amount of oxalic acid, which each 1 cc of the solution must contain in order that it may be exactly equivalent to 1 cc of CO_2; $\frac{126}{44} \times 0{\cdot}001971 \times 1000 =$ 5·645 grammes.

Where lime water is used it can be shown that the same equation in regard to CO_2 and $H_2 C_2 O_4$ holds good, because the difference in the first and second alkalinities depends on the amount of CO_2 which has been absorbed by the $Ca (OH)_2$, the only difference which may arise depends upon the avidity of $Ba (OH)_2$ being greater than $Ca (OH)_2$ for CO_2, so that when employing lime water it is usual to expose the air to it for a longer period.

$$H_2 C_2 O_4 + 2 H_2 O + Ca (OH)_2 = Ca C_2 O_4 + 4 H_2 O$$
$$CO_2 + Ca (OH)_2 = Ca CO_3 + H_2 O$$
$$H_2 C_2 O_4 = CO_2$$
$$126 H_2 C_2 O_4 = 44 CO_2$$
$$\tfrac{126}{44} H_2 C_2 O_4 = 1 CO_2$$

The detail for performing Pettenkofer's test is as follows :—

(1). Collect the sample of air by one of the methods already indicated.

(2). Add to it 60 cc of baryta or lime-water from a syphon stock-bottle, having a guard tube containing soda-lime so that no CO_2 can reach the baryta or lime-water in this stock-bottle ; set aside from ½ to 1 hour.

(3). Titrate 30 cc of the baryta water at the time when the baryta water was added to the sample of air, noting the number of cc of standard acid required to discharge the colour after first adding a few drops of the phenolphthalein solution; call this amount A.

(4). Now titrate 30 cc of the baryta added to the bottle of air, and call this result B.

(5). Then A — B = difference in causticity before and after exposing baryta water to air, and for the reason previously stated this difference in cc after multiplying by 2 gives the number of cc CO_2 contained in the sample of air.

Example : 30 cc baryta water (A) required 28 cc standard acid ; 30 cc baryta water (B) required 26 cc standard acid.

Difference for 60 cc = 4 cc this ∴ = 4 cc CO_2 measured at 0° C. + 760 mm pressure.

The sample of air originally taken was contained in a bottle of, say 4060 cc capacity, and as 60 cc of air were displaced when the 60 cc of baryta water were added, there were therefore only 4060 — 60 cc of air in the bottle = 4000 cc. 4000 cc air contain 4 cc CO_2 ∴ 1000 cc contain 1 cc.

Now the strength of our acid solution was calculated for 0° C. and 760 mm pressure, so that if for example the sample of air was taken with the pressure at 770 mm and 20° C., we must calculate how much was actually present at that temperature and pressure.

By Boyle's law the temperature being constant, the volume varies inversely with the pressure ; and by Charles or Gay-Lussac's law, at constant pressure the volume of a gas is proportional to its absolute temperature ; gases expanding $\frac{1}{273}$ for every 1° C. and the absolute temperature at 0° C. = 273°, or if working with degrees Farenheith then we must remember that gases expand $\frac{1}{491}$ for every 1° F., and 32° F. = 459° absolute temperature. So combining these two laws we have—

$$\frac{\textit{V found} \times \textit{standard pressure.}}{\textit{Standard temperature in absolute degrees.}} = \frac{\textit{V required} \times \textit{existing pressure.}}{\textit{Existing temperatvre in absolute degrees.}}$$

So in the example given we have—

$$\frac{1 \times 760}{273} = \frac{x \times 770}{293}$$

NOTE.—In correcting for pressure, it is always easier to work with the height of barometer in millimeters instead of inches in order to avoid fractions. Inches may be converted into millimeters by dividing by ·03937, or by multiplying the height in inches by 25·4.

Or it can be stated thus—

$$1 \times 760 : 273 :: x \times 770 : 293$$

$$\text{or} \quad \frac{1 \times 760 \times 293}{770 \times 273} = x$$

which worked out comes to 1·05 cc.

Analyst, p. 184, Vol. XVII. Dr. Gill estimates CO_2 by taking dry bottles capable of holding 4400 to 8800 cc, filling them with air with bellows, 15 strokes of which will fill a 4 litre bottle four times, thus ensuring a representative sample. 50 cc of barium hydrate solution are rapidly run into a bottle of air, the bottle is stoppered, capped, and placed on its side and shaken at intervals for 40 or 60 minutes, at the end of which time the cap and stopper are removed, the bottle inverted over a 50 cc glass stoppered bottle so that the solution shall come in contact with the air as little as possible, 15 to 20 cc are withdrawn with a narrow stemmed 15 or 20 cc bulbed pipette and titrated with sulphuric acid (1 cc of which = 1 milligramme CO_2), using rosolic acid as an indicator. The difference between the number cc of standard acid required to neutralise the amount of barium hydrate before and after absorption gives milligrammes of CO_2 present in bottle; milligrammes CO_2 can be converted into cubic centimeters as already detailed, the usual corrections for temperature also being made.

NOTE.—The acid may be prepared by diluting 46·51 cc normal H_2SO_4 to a litre.

Lunge and Zeckendorf's method.—Another method which, like Pettenkofer's, depends for its action on the reduction of alkalinity of an alkaline solution exposed to CO_2, is that known as Lunge and Zeckendorf's method, the indicator, as before, is phenolphthalein, and the solution employed is $\frac{N}{500}$ $Na_2\ CO_3$; instead of adding the alkaline solution to the air, in this case we keep passing known quantities of air through the solution until the colour is discharged, the air is caused to flow through the solution by pressing a rubber ball which is connected with one of two tubes arranged like the tubes of a wash bottle, the rubber ball is practically a Higginson's syringe and like it, is furnished with two valves which cause the air to flow only in one direction ; it delivers 70 cc of air each time the rubber ball is filled and emptied. By noting the number of times the ball is compressed, and referring to a table furnished with the apparatus, the amount of CO_2 in the air is approximately ascertained. For example : If on compressing the ball twice the colour is discharged, this indicates that there are 3·0 parts per 1000 of CO_2 in the air ; 20 compressions show that the limit of respiratory impurity has been slightly exceeded, viz., 0·62 parts per 1000 of CO_2 in the air ; and if the ball has to be compressed 35 times before the colour goes, then we know that the air of the room does not differ sensibly from the outside air, viz., 0·42 parts CO_2 per 1000 of air.

We mentioned in connection with this apparatus a solution of $Na_2\ CO_3$ $\frac{N}{500}$ strength, this signifies that the solution is $\frac{1}{500}$th of the normal strength ; a normal solution contains the hydrogen equivalent weighed in grammes of the active constituent of substance dissolved in a litre of water at 16° C. In the case of a univalent substance, the atomic weight (or in the case of a salt the molecular weight) and the amount of the substance contained are identical. In the case of bi-valent, tri-valent, etc., it is $\frac{1}{2}$ or $\frac{1}{3}$ of the atomic (or in the case of a salt the molecular) weight. For example : A normal solution of HCl contains 36·37 grammes HCl in a litre. In the case of $H_2\ SO_4$ it would be $\frac{98}{2} = 49$ grammes $H_2\ SO_4$. Fractions of the normal, such as semi-normal, deci-normal, etc., are represented $\frac{N}{2}$, $\frac{N}{10}$, etc.

In the fluid used with Lunge and Zeckendorf's apparatus deci-normal solution of anhydrous sodium carbonate is prepared, and coloured by dissolving in it 1 gramme of phenolphthalein. This keeps well in a properly closed bottle, whereas weaker solutions will not. For use this is made into $\frac{N}{500}$ $Na_2\ CO_3$ as required, by taking 2 cc and diluting up to 100 with pure recently boiled distilled water free from CO_2, 10 cc of this are then put in the bottle connected, as already described, with the rubber ball ; this $\frac{N}{500}$ $Na_2\ CO_3$ should be freshly prepared when required for use, as it will only keep for a short space of time.

Directions for use.

If the average quantity of carbonic acid in the air of a chamber is to be tested, the air must be well mixed before the sample is drawn; if the air in one portion only is to be taken, the free end of the indiarubber ball must be placed in it, and the ball pressed several times by the hand in order to fill both ball and bottle with the air. The bottle is then opened, and 10 cc of the test solution introduced by means of a 10 cc pipette (but the pipette must not be blown into), the stopper of the bottle quickly replaced, and the bottle shaken rapidly for about a minute, the indiarubber ball is then slowly but firmly pressed together, so that the air streams through the fluid, and the bottle shaken as above, and this repeated until the red colour in the solution is discharged.

From the number of times it is necessary to press the ball, the carbonic acid in the air is calculated by the table herewith; if only a few pressures are necessary, the air of the space tested is very bad; if from nine to ten pressures, moderately good; if from twenty to twenty-five, very good; in the open air forty to fifty pressures are required. If the proportion of carbonic acid is large, the discharge of colour is sharp and complete, in pure air the change is uncertain within two or three pressures, and a complete discharge is difficult to obtain. But in pure air three pressures only cause a difference in the third decimal point.

Table.

Number of Pressures of Indiarubber Ball.	Parts per 1,000 of Carbonic Acid in the Air.	Number of Pressures of Indiarubber Ball.	Parts per 1,600 of Carbonic in the Air.
2	3·0	16	0.71
3	2·5	17	0·69
4	2·1	18	0·66
5	1·8	19	0·64
6	1·55	20	0·62
7	1·35	22	0·58
8	1·15	24	0·54
9	1·0	26	0·51
10	0·9	28	0·49
11	0·87	30	0·48
12	0·83	35	0·42
13	0·8	40	0·38
14	0·77	48	0·30
15	0·74		

Angus Smith's method.—Angus Smith estimates the CO_2 in the air, by taking a series of bottles varying in capacity from 20.63 ounce down to 2·5 ounce, and adds ½-oz. of lime water to each, commencing with the largest until he reaches

Fig. 35*a*.—Lunge & Zeckendorf's Apparatus.

and especially the anthracite variety, is burnt in *cast-iron* stoves; red-hot cast-iron allows CO gas to escape through it by occlusion, whereas *wrought-iron* stoves are free from this objection.

Carbonic oxide is known to escape through the joints in stoves, and in the case of cast-iron the carbon contained in it at high temperatures reduces carbon dioxide to monoxide.

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* In the Russian Navy, pyro-collodion powder is employed, which yields 54·54 volumes per cent. of CO as a result of the deflagration of pyro-collodion $C_{30}, H_{38}, N_{12}, O_{49} = 30\,CO + 19\,H_2\,O + 6\,N_2$.

Another source of CO in the air, is when a gas-flame is used to heat water, as in some varieties of "water-heaters" the cold surface coming in contact with the gas interferes with combustion, and carbon monoxide enters the air. The escape of coal-gas is a frequent cause of CO poisoning, as it contains about 4 to 7 per cent. of carbon monoxide.

"Water-gas" has on several occasions caused deaths from carbonic oxide, as recorded in *Lancet* for 28th December, 1889; in this case water-gas, which consists of hydrogen and carbonic oxide, escaped into a room, and being odourless was unnoticed. If this gas is employed it should be odorised, in order that any escape may be speedily detected.

The detection of carbon monoxide in air is a very simple matter if a spectroscope be available; the test, which is known as Vogel's, is conducted as follows:—

A sample of the suspected air is obtained in the ordinary manner already described, and to this is added a few drops of a very weak solution of blood, just showing a faint red colour; after being well shaken up it should be examined with the spectroscope; two dark bands will be seen in the spectrum in the yellow and green parts of the solar spectrum between Fraunhofer's lines D and E. If these lines be due to oxy-hæmoglobin, they will disappear on the addition of a drop or two of colourless ammonium sulphide solution, and in their place will appear one broad band, shaded off at the edges, intermediate between them. If the dark bands were due to carboxyhæmoglobin, no marked change is noticeable, showing that carbonic oxide forms a stable compound with hæmoglobin.

The left absorption band of carboxyhæmoglobin, *i.e.*, the one at the yellow end of the spectrum, lies more to the right than is the case with the oxy-hæmoglobin.

The test conducted with a drop or two of blood as above will, according to Vogel, detect even 0·25 per cent. of CO.

If greater precision is required, a mouse in a wire cage is kept in the suspected atmosphere, and after a time drowned, divided in the region of the heart, and the blood examined as before; 0·03 per cent. of CO, if present, can be shown by this method.

As a control a similar experiment with a mouse kept in the open air may be performed.

In the *Analyst* for September, 1897, page 249, Vol. XXII., a reaction of carbon monoxide, in which a weak solution of $K_2 Mn_2 O_8$ acidified with HNO_3 is decolourised by CO, is given; if silver nitrate be added the reaction is more speedily obtained. M. Mermet described the test, and states that the reagents must be used fresh, the air should be filtered through cotton wool and passed through absorptive reagents to remove dust or gases such as hydrogen sulphide, liable to decolourise the permanganate solution; a control test with normal air may with advantage be performed. The reagents are prepared as follows:—2 to 3 grammes of crystalized silver nitrate are dissolved in a litre of water.

The permanganate solution is prepared by boiling 1 litre of distilled water with a few drops of pure nitric acid, and destroying any organic matter present by adding a few drops of permanganate solution, when cold, 1 gramme of permanganate crystals and 50 cc of pure nitric acid are added, and the solution stored away from light and dust.

The reagent is prepared, immediately before use, by mixing 20 cc of the silver nitrate solution with 1 cc of the permanganate solution, 1 cc of pure nitric acid, and 28 cc of distilled water freed from organic matter.

To apply the test the reagent is poured into a flask containing the air under examination, and precautions against dust or reducing agents taken as indicated above.*

Organic matter in air, the result of respiration and transpiration, *i.e.*, given off from the skin and lungs, is (*a*) nitrogenous; (*b*) oxidisable; (*c*) organic; and (*d*) putrescent; because (*a*) it will yield ammonia; (*b*) it will reduce a solution of $K_2\ Mn_2\ O_8$, as shown by the bleaching effect; (*c*) it is charred by $H_2\ SO_4$, as shown by drawing air known to contain this animal organic matter through $H_2\ SO_4$, which renders it dark coloured; (*d*) if air containing the organic matter be drawn through pure sterile distilled water it will putrefy and give off offensive smelling gases.

Estimation of Organic Matter in Air.

Organic matter in the air can be estimated quantitatively by aspirating known quantities of air through doubly distilled

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* Miners are often killed in colliery explosions by the "after-damp," a mixture of gases, amongst which CO is met with. The rescue party are subjected to the same risk of asphyxia from this "after-damp" as those who were in the explosion. As a safeguard, Haldane has recommended that those forming the rescue party should take with them a cage containing mice, and cylinders of oxygen gas. Mice breathe much more rapidly than human beings, are much sooner affected with signs of CO poisoning, and the death of the mice would serve as a warning, and enable the rescuers to escape, since the candle will continue to burn brightly in air containing "after-damp," whereas with the "choke-damp" the CO_2 speedily extinguishes the light.

Artificial respiration and inhalation of oxygen and fresh air, with the administration of stimulants and maintenance of bodily temperature, are, according to Dr. Clifford Allbutt, the chief points to which attention should be turned.

water. (*a*) And then we can estimate this by the Wanklyn process as detailed under water analysis; or (*b*) determine the amount of oxidisable matter by the amount of oxygen absorbed by the Tidy-Forchammer process also described under water analysis; or lastly (*c*) collect a sample of air, as in Pettenkofer's process, and add to this bottle 50 cc of $\frac{N}{1000}$ $K_2 Mn_2 O_8$. $\frac{N}{1000}$ $K_2 Mn_2 O_8$ is made by taking 100 cc of $\frac{N}{10}$ $K_2 Mn_2 O_8$ and adding to it 50 cc of 1 : 6. $H_2 SO_4$ and distilled water to make up to one litre.

Since 1 cc of $\frac{N}{10}$ $K_2 Mn_2 O_8$ has 0·0008 grammes or 0·8 milligrammes of available oxygen each, 1 cc of $\frac{N}{1000}$ has 0·008 milligrammes of available oxygen. Shake up and leave for ten minutes, then take 25 cc of this $K_2 Mn_2 O_8$ solution, make this up to 150 cc, and label it *sample;* and also take 25 cc of the original unexposed $\frac{N}{1000}$ $K_2 Mn_2 O_8$ solution, make it up to 150 cc, label it *standard.*

Place the two measures containing these solutions side by side, taking care that each one is of the same calibre, compare the colours, and from a burette run in sufficient $\frac{N}{1000}$ $K_2 Mn_2 O_8$ to equalise the colours, read off and note the amount which was required to match the sample with the standard, and the calculation is performed as follows:—1 litre of oxygen weighs 15·96 × 0·0896 = 1·43 grammes, therefore 1 cc of O_2 = 0·00143 grammes, or in other words 1·43 milligrammes, so 1·43 : ·008 :: 1 : x which = 0·00559 cc, *i.e.*, in round numbers 0·0056 cc of O_2 at 0° C × 760 mm. pressure.

Multiply by 2, the number of cc $\frac{N}{1000}$ $K_2 Mn_2 O_8$ required to bring the colour in the solution exposed to the air in the bottle, up to that of 25 cc of the standard, because 50 cc were placed in the bottle and only 25 cc were tested, and by a proportion sum find the amount of oxygen absorbed in vols. per million of the air under examination.

For example: Sample bottle containing air held 3050 cc, and 50 cc of $\frac{N}{1000}$ $K_2 Mn_2 O_8$ were run in, which displaced 50 cc of of air, the nett capacity of the gas was therefore 3050 − 50 = 3000, in order to make the colour in the *sample* tube match that of the standard tube, it was found necessary to add 1·5 cc $\frac{N}{1000}$ $K_2 Mn_2 O_8$ solution, ∴ 1·5 × 2 would have been required for the 50 cc, *i.e.*, 3 cc, then the amount of oxygen absorbed per million volumes of air is found as follows:—

$$3000 : 1{,}000000 :: 3 : x$$

$$x = \frac{3{,}000000}{3000} = x = \frac{1000}{1}$$

$$x = 1000 \text{ cc}$$

Now each 1 cc = ·0056 cc of O_2, so 1000 × ·0056 = 5·6 per million = amount of O_2 per million required, which would be an excessive amount, as air should not, as a rule, require more than 4 or 5 vols. per million, and Carnelley and Haldane say that pure air should not require more than 2 vols. per million in order to oxidise organic matter present.

Corrections should be made for temperature and pressure, as was done when performing Pettenkofer's test for CO_2.

Estimation of Oxygen in Air.

It is sometimes considered advisable to estimate the amount of oxygen contained in the air; as we have already said a deficiency of oxygen generally implies contamination, because hurtful gases have taken its place. The O_2 in the outside air varies slightly, it is usually present to the extent of 20·96 per cent., in occupied rooms it is often reduced to 20·97, and in mines it has been known to fall as low as 18·27 per cent., whereas in respired air it is present to the extent of only 16·033 per cent.

It can be estimated by means of the eudiometer (which means the measure), (*metron*) of the clearness or purity of the air, (*eudios*) clear weather. This is conducted as follows:—

A certain amount of air is introduced into a strong glass tube (eudiometer), previously filled with mercury, the air should not be more than enough to occupy about one-sixth, and the amount should be accurately measured, hydrogen gas is next introduced in sufficient quantity to combine with all the air present, and after taking precaution against the escape of the gas, an electric spark is made to pass through the mixture, an explosion occurs, and the volume of the gases is diminished, the amount of diminution is determined, and one-third of this diminution being oxygen, since 2 vols. of hydrogen combine with one of oxygen to form water; say 100 cc of air and 50 cc of hydrogen were taken, making a total of 150 cc, after the explosion there remains say 87·12 cc, then 150 − 87·12 = 62·88 cc and $\frac{62·88}{3}$ = 20·96 cc the amount of oxygen in the 100 cc of air which were taken.

A simpler method is to employ a Hempel's absorption pipette, this may be either a single or double pipette, according to the substance used to absorb the oxygen.

If nitric oxide NO be employed, the experiment is conducted as follows:—The lower bulb and the greater part of the upper one are filled with water, this is connected with a graduated tube by means of a piece of tight-fitting rubber tubing furnished with pinchcocks, the graduated tube is connected with another tube by means of rubber tubing, and water is poured in until it stands at the same level in the two tubes, and so arranged as to allow of the desired amount of air being contained in the measuring tube ; the tube which is

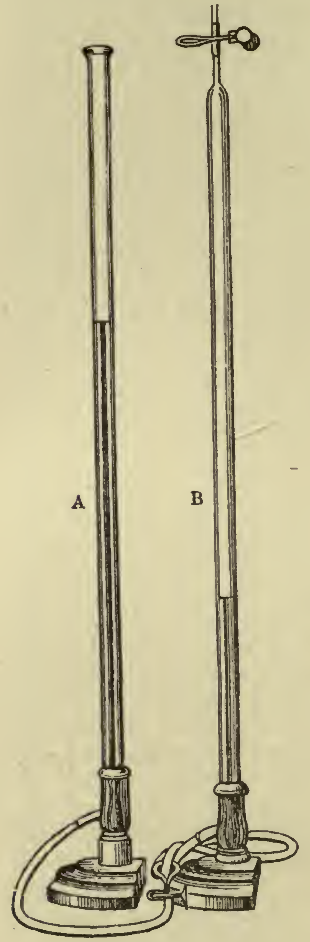

Fig. 35.

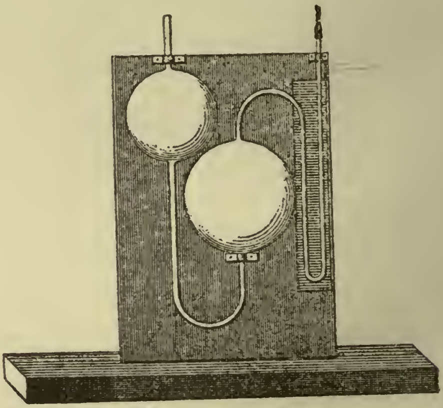

Fig. 35.

to contain the sample of air is now disconnected from the absorption pipette, and by raising the other the water is made to first fill it, and then allowed to fall back to its original level by lowering the other tube, a measured amount of nitric oxide is now enclosed and made to pass over into the absorption apparatus, and the pinchcock applied; next a measured quantity of air is taken in, and this is in turn passed over, as was done with the nitric oxide, into the absorption pipette, ruddy fumes at once appear, which consist of $N_2 O_3$ and NO_2, the result of the union of the NO with the O, these are dissolved by the water, and the volume is thereby diminished, one-third of this diminution, as in the previous experiment, will be oxygen, and the calculation is made as before.

In some laboratories pyrogallic acid and caustic potash, dissolved in water, are employed to absorb the oxygen present, and, as in the above experiment, the gas remaining after the absorption is complete and measured, in this case the solution used consists of pyrogallic acid, 15 grammes; caustic potash, 50 grammes; distilled water to the litre; and the pipette employed is one known as Hempel's double absorption bulb, the first of the series contains the absorbent, the next is empty, the third contains water, and the fourth is empty and can be guarded by a soda-lime guard tube.

Detection of Gases.

The following tests are intended for candidates for diplomas in State medicine, who at the various examinations are often called upon to determine the nature of certain gases supplied in bottles :—

(1). Partially remove the stopper and cautiously smell the gas contained in the bottle. (2). Replace stopper, catching pieces of red and blue litmus between the stopper and the bottle, having previouly moistened the litmus papers with pure distilled water, note any change of colour which may occur, if the blue litmus paper is first reddened and then bleached, and the red litmus paper is bleached, the gas is probably chlorine; catch a strip of filter paper moistened with KI solution between the stopper and the side of the bottle, note any change, if it is first darkened and then bleached, the gas is chlorine; as a confirmatory test, moisten a piece of filter paper with KI solution and starch paste, if this is turned blue, the gas is chlorine.

The other gases which will redden blue litmus paper are HCl. HNO_3, nitrous fumes (composed of a mixture of NO, $N_2 O_3$, and NO_2), sulphur dioxide, and, in a doubtful way, $H_2 S$ and CO_2. Next proceed to find out which of these gases it is, add to the bottle of gas under examination about 10 or 15 cc of pure distilled water, shake and pour into a test tube, if the gas is HCl, on the addition of $AgNO_3$ and HNO_3 dilute, a permanent white precipitate or cloud will be formed; and as a confirmatory test, a glass rod dipped in a strong solution of ammonia and introduced into the bottle causes white fumes. If no permanent precipitate with $AgNO_3$ and HNO_3, as above, add to some of the fluid in a test tube a little brucine solution, if it be HNO_3 an immediate purple colour is formed, which soon turns yellow; and as a confirmatory test, add a crystal of ferrous sulphate and a little H_2SO_4 dilute, if the crystal turns brown it indicates nitric acid HNO_3.

If there be doubt as to the above, add a little KI solution and starch paste to some of the liquid, an immediate blue colour denotes nitrous, and not nitric acid.

If none of the above tests have been shown except the reddening of the litmus, then to some of the fluid, in a test tube, add a piece of zinc and a little HCl, warm and hold a piece of filter paper, moistened with lead acetate solution, over the test tube, darkening denotes H_2S, the result of the reduction of the SO_2, thus $SO_2 + 6\,HCl + 3\,Zn = H_2S + 3\,ZnCl_2 + 2\,H_2O$, or to some of the fluid add a little bromine water, the colour disappears, and on the additions of $BaCl_2$ and HCl a white precipitate forms, indicating sulphates, the result of the oxidation of sulphates, which was effected by the bromine water as follows:—$H_2SO_3 + Br\,2 + H_2O = 2\,HBr + H_2SO_4$.

In the other two cases where the reddening of the litmus is doubtful, there will be an odour of H_2S, and a piece of filter paper moistened with lead acetate solution held in the bottle is blackened, indicating H_2S; or if there is no odour of H_2S, then on adding a little lime water this is immediately rendered turbid, and the gas is CO_2.

If the litmus paper was turned blue, the gas is either ammonia or ammonium sulphydrate, in both of which cases there will be an odour of ammonia, and in the latter case the additional odour of H_2S.

On the addition of water if the gas is simply ammonia, the solution turns brown on the addition of Nessler's solution, and a glass rod dipped in hydrochloric acid forms white fumes on being introduced into the bottle indicating ammonia.

In the other case the fluid in a test tube, on the addition of nitroprusside of sodium solution, shows a violet colour, indicating the presence of ammonium sulphydrate.

The remaining gases to test for are bisulphide of carbon (CS_2) and carbon monoxide (CO), which have no effect on litmus paper. CS_2 has an unpleasant odour, and on the application of a light burns with a blue flame, and a deposit of sulphur remains.

Carbon monoxide being too dangerous would not be submitted for trial, but if it were, Vogel's spectroscopic test, with a dilute solution of blood, would reveal its presence.

Bacteriological Examination.

The bacteriological examination of the air of a room should be conducted, if possible, at a time when the air is still; if we require a qualitative examination only, Petri's dishes or glass plates containing agar-agar or nutrient gelatine may be exposed for varying intervals, and these are then covered with sterile covers and incubated at temperatures varying with the medium employed, 22° C. is the usual temperature, the nature of the resulting colonies can be examined and subcultures made if required; or better still, a known quantity of air is drawn through a sterile tube, guarded by sterile rubber caps, the aspiration being effected by bottles filled with water, by altering the position of which water flows alternately from one to the other, and, by so doing, draws air through the glass tube which is coated with nutrient-gelatine;

Fig. 36—Hesse's Apparatus.

after a given quantity of air has been drawn through the tube, the gelatine can be melted at a low temperature and plates set therewith, or the micro-organisms allowed to grow *in situ* on the tube. The apparatus usually employed is that known as Hesse's (*Fig. 36*), and this is furnished with tripod, tube, clamps, and caps. The tube is 61 cm long and about 4 cm in diameter, closed at one end by a caoutchouc stopper, perforated for a glass tube connected with an aspirator, the other is closed by two tightly fitting rubber caps, the inner of which is perforated. When it is required to draw air through the tube, the unperforated cap is removed and the process of aspiration commences.

CHAPTER VII.

MILK.

Milk is an important article in Naval Hospitals and for use in a sick mess on board a ship, but otherwise does not enter into the Service dietary. The milk of each animal is a perfect food for its own young, as it includes the proper proportions of all the necessary elements, but when for example the milk of a cow is used for young infants it is subject to the disadvantage of containing too much nitrogenous material and too little sugar; when diluted so as to reduce the amount of proteid material it then contains too little fat. In the case of an adult doing moderate work and requiring about 4½ ounces of nitrogenous food, 3 ounces of fat, 15 ounces of carbohydrates and 1¼ ounces of salts to get the requisite amount of nitrogen and carbon, viz., 300 grains nitrogen and 5000 grains carbon, he would require about 7 pints, and then would have a considerable excess of nitrogen and a deficiency, to a slight extent, of carbon. On the Mediterranean station the milk of goats and ewes is frequently the only milk obtainable. Composition of goats' and ewes' milk. *

Constituents.		*Goat.*	*Ewe.*
Water	per cent	84·06	75·22
Fat	,,	5·80	11·28
Milk Sugar ...	,,	4·94	3·58
Proteids	,,	4·20	8·83
Mineral matter ...	,,	1·0	1·69
Specific Gravity ...	...	1·032 to 1·037	1039·3

Milk is composed of water, fat in the form of an emulsion, the globules of which vary in size from 0·000053 to 0·0004 of an inch in diameter, proteids in the form of lactalbumin and casein.

The examination of milk is conducted for the purpose of ascertaining its quality and detecting adulterations or the

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*[*B.M. Journal*, 31st Dec., 1898.

addition of preservatives; as to whether or not preservatives added to a small extent are harmful or not, is a point which authorities are not agreed upon.

Some preservatives are only required in infinitesimally small amount, for example, formalin need only be present to the extent of 0·003 per cent. to keep milk good for three days, and 0·0125 per cent of formalin will preserve milk for seven days, whereas 0·05 per cent. boric acid will not keep milk sweet for more than four or five days.

Examination of Milk.

(*I.*) *Physical Characters.* It should be of a full opaque white colour, with perhaps the faintest tinge of yellow, it should not show any deposit on standing, the taste and smell should be agreeable; under the microscope it should show innumerable fat globules of sizes varying between $\frac{1}{20000}$ and $\frac{1}{2500}$ of an inch, but if the milk be from a cow immediately after calving much larger fat particles will be seen, varying in size from $\frac{1}{4000}$ to $\frac{1}{1000}$ of an inch in diameter, when it contains these particles the milk is known as the colostrum or "beestings" and is unfit for human food.

The reaction of the milk should be neutral or faintly acid, when fresh drawn it is amphioteric, that is to say it both reddens blue litmus paper and turns red litmus blue. The specific gravity of milk taken at 60° F. varies between 1·028 and 1·035, but the average is 1·032. Good milk should yield from 6 to 11 per cent. of cream, and in certain breeds even 40 per cent. of cream. Cream is fat which has separated and risen to the surface on standing; the fat globules at one time were thought to consist of fat globules each encased in very thin albuminous envelopes, but this is now known not to be so.* The average composition of cows' milk is, according to Pearmain and Moor, as follows:—

Water	87·6	per cent.
Fat	3·6	,,
Milk Sugar	4·8	,,
Proteids	3·3	,,
Mineral matter ...	0·73	,,
That is total solids	12·4	,,
Fat	3·6	,,
Solids not fat	8·8	,,

The average composition of 120,540 samples of milk, according to Dr. Vieth, was—

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* Vide *B.M.J.* 17, ix., 98. page 779.

Total solids	12·9 per cent.
Fat	4·1 ,,
Solids not fat ...	8·8 ,,

Whilst the official standard of purity according to the Inland Revenue Department Laboratory, Somerset House, is—

Total solids	11·25 per cent.
Fat	2·75 ,,
Solids not fat	8·5 ,,

A standard which errs on the side of leniency.

The Society of Public Analysts have fixed a slightly higher standard as the minimum, viz.—

Total solids	11·5 per cent.
Fat	3·0 ,,
Solids not fat ...	8·5 ,,

And these figures are the ones which we employ when calculating the amount of fat abstracted or added water in samples of adulterated milk.

For ordinary purposes it is sufficient to determine the total solids per cent. by weight; fat per cent. by weight; amount of ash per cent. by weight; per centage of cream by volume; and specific gravity at 60° F., in addition to noting the reaction, physical character, and presence or absence of adulterants or preservatives.

Specific gravity is taken after first carefully shaking the sample by means of a hydrometer, or if greater accuracy is required by a Westphal balance, the temperature must be noted, and if it is not 60° F. the specific gravity must be corrected for temperature by means of the table on next page.

The total solids are determined by taking 5 cc of milk in a carefully weighed platinum dish, weighing the 5 cc before and after evaporating to dryness. For example: Platinum dish weighs 33.5 grammes; platinum dish with 5 cc of milk weighs 38·66 grammes; 38-66 − 33·5 = 5·16, which is the weight of the milk taken, after drying, weight is 34·145; 34·145 − 33·5 = 0.645, which equals total solids in 5·16 grammes of milk;

$$\frac{\cdot 645 \times 100}{5\cdot 16} = 12\cdot 5 \text{ per cent. total solids.}$$

Ash. This is obtainable by incinerating the residue left after evaporation to dryness at as low a temperature as possible until it is quite white, the ash is then calculated to per centage as before, *e.g.*—

Observed Specific Gravity.	Degrees of Thermometer (Fahr.)																					Observed Specific Gravity.
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	
1·020	19·2	19·3	19·4	19·4	19·5	19·6	19·7	19·8	19·9	19·9	1·020	20·1	20·2	20·2	20.3	20·4	20·5	20·6	20·7	20·9	21·0	1·020
1·021	20·2	20·3	20·3	20·4	20·5	20·6	20·7	20·8	20·9	20·9	1·021	21·1	21·2	21·3	21·4	21·5	21·6	21·7	21·8	22·0	22·1	1·021
1·022	21·2	21·3	21·3	21·4	21·5	21·6	21·7	21·8	21·9	21·9	1·022	22·1	22·2	22·3	22·4	22·5	22·6	22·7	22·8	23·0	23·1	1·022
1·023	22·2	22·3	22·3	22·4	22·5	22·6	22·7	22·8	22·8	22·9	1·023	23·1	23·2	23·3	23·4	23·5	23·6	23·7	23·8	24·0	24·1	1·023
1·024	23·2	23·3	23·3	23·4	23·5	23·6	23·6	23·7	23·8	23·9	1·024	24·1	24·2	24·3	24·4	24·5	24.6	24·7	24·9	25·0	25·1	1·024
1·025	24·1	24·2	24·3	24·4	24·5	24·6	24·6	24·7	24·8	24·9	1·025	25·1	25·2	25·3	25·4	25·5	25·6	25·7	25·9	26·0	26·1	1·025
1·026	25·1	25·2	25·2	25·3	25·4	25·5	25·6	25·7	25·8	25·9	1·026	26·1	26·2	26·3	26·5	26·6	26·7	26·8	27·0	27·1	27·2	1·026
1·027	26·1	26·2	26·2	26·3	26·4	26·5	26·6	26·7	26·8	26·9	1·027	27·1	27·3	27·4	27·5	27·6	27·7	27·8	28·0	28·1	28·2	1·027
1·028	27·0	27·1	27·2	27·3	27·4	27·5	27·6	27·7	27·8	27·9	1·028	28·1	28·3	28·4	28·5	28·6	28·7	28·8	29·0	29·1	29·2	1·028
1·029	28·0	28·1	28·2	28·3	28·4	28·5	28·6	28·7	28·8	28·9	1·029	29·1	29·3	29·4	29·5	29·6	29·8	29·9	30·1	30·2	30·3	1·029
1·030	29·0	29·1	29·1	29·2	29·3	29·4	29·6	29·7	29·8	29·9	1·030	30·1	30·3	30·4	30·5	30·7	30·8	30·9	31·1	31·2	31·3	1·030
1·031	29·9	30·0	30·1	30·2	30·3	30·4	30·5	30·7	30·8	30·9	1·031	31·2	31·3	31·4	31·5	31·7	31·8	32·0	32·2	32·2	32·4	1·031
1·032	30·9	31·0	31·1	31·2	31·3	31·4	31·5	31·6	31·7	31·9	1·032	32·2	32·3	32·5	32·6	32·7	32·9	33·0	33·2	33·3	33·4	1·032
1·033	31·8	31·9	32·0	32.1	32·3	32·4	32·5	32·6	32·7	32·9	1·033	33·2	33·3	33·5	33·6	33·8	33·9	34·0	34·2	34·3	34·5	1·033
1·034	32·7	32·9	33·0	33.1	33·2	33·3	33·5	33·6	33·7	33·9	1·034	34·2	34·3	34·5	34·6	34·8	34·9	35·0	35·2	35·3	35·5	1·034
1·035	33·6	33·8	33·9	34·0	34·2	34·3	34·5	34·6	34·7	34·9	1·035	35·2	35·3	35·5	35·6	35·8	35·9	36·1	36·2	36·4	36·5	1·035

Platinum dish and ash weighs 33·538 grammes; $33{\cdot}538 - 33{\cdot}5 = 0{\cdot}038$;

$$\frac{0{\cdot}038 \times 100}{5{\cdot}16} = 0{\cdot}736$$

It is important to note the amount of ash; as a rule this varies from about 0·73 to 0·75 per cent. If there be excess of ash add to it some dilute HCl, effervescence indicates the addition of a carbonate, and probably this was sodium bicarbonate added to neutralise acidity in milk slightly turned. Or if the ash be excessive evaporate some more milk to dryness and test for boric acid as detailed subsequently.

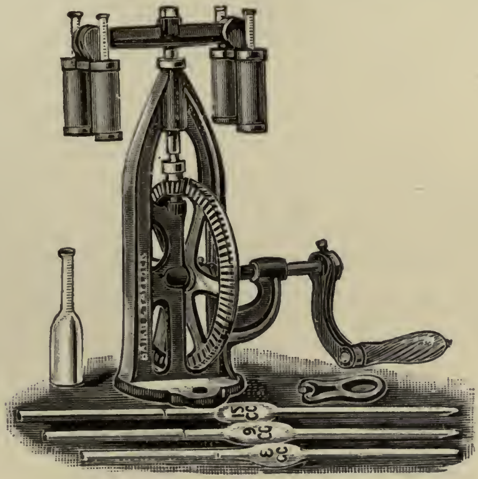

Fig. 37. Leffmann-Beam Apparatus.

Fat. The most convenient method of estimating fat is that known as the "Leffmann-Beam" process, of which there are several modifications, depending for their action on the running together of fat globules which occurs when an acid such as hydrochloric acid and fusel oil are added to milk; fusel oil is an essential, as it is found that without it the milk globules do not as readily coalesce.

The fat globules set free are brought to the surface by means of a centrifugal apparatus. The Leffmann-Beam apparatus consists of a vertical rod connected to a series of highly geared wheels, giving a large number of revolutions per minute. The upright rod supports a horizontal one, at either end of which are four metal carriers which hang vertically when the apparatus is still, but are horizontal when revolving rapidly; in each of these fits a small graduated bottle which holds the milk and re-agents.

The process is conducted as follows :—

Take 15 cc of milk from a sample which has been well mixed, pour this out into a Nessler glass and add 3 cc of a mixture of equal parts of fusel oil and strong hydrochloric acid, mix well, next add slowly drop by drop 9 cc of strong sulphuric acid, mixing the acid and milk together carefully so that when all the acid has been added there are no undissolved masses of curd remaining: next pour out this mixture of (1) milk, (2) hydrochloric acid and fusel oil, and (3) sulphuric acid into one of the bottles supplied with the apparatus, add to this mixture in the little graduated bottle some 50 per cent. sulphuric acid sufficient to fill up to the 0 on the scale, if freshly mixed it will always be hot enough, but if made some time before it will be necessary to warm the sulphuric acid and water, and before pouring it into the small graduated bottle it is well to pour a little of this 50 per cent. acid into the tube in which the milk was mixed with the reagents in order to rinse out any of the mixture which might have been left behind. Before commencing to whirl the milk, care must be taken to see that three other carriers are equally weighted with similar bottles filled, if necessary, with sulphuric acid and water, as a rule the bottles from previous analyses will be available to act as counterpoises. Next cause the bottles to revolve smartly by turning the handle moderately quick, then after two minutes, or if dealing with poor milk three minutes, the machine is stopped and the sample examined, when the fat as a clear layer of oil will be found floating on a dark brown clear fluid, the number of degrees over which the fat extends tells us the per centage of fat, each ten divisions indicating 1 per cent. of fat; for example, after whirling the milk for two minutes the fat was found to occupy 34 divisions, there is therefore 3·4 per cent. of fat.

If we have estimated the fat by this apparatus (or any other method), and have also determined the true specific gravity at 60° F, we can determine the amount of total solids by means of Richmond's slide rule (*Fig. 38*). This consists of a rule 12 inches long on which three scales are marked. On the top is the fat, in which every 1·167 inch is divided into tenths. The sliding part has an arrow marked on its upper margin carrying the various specific gravities, each division being 0·25 inch in length; the total solids are marked on the lowest scale, each division is 1 inch long divided into tenths and indicating total solids from 17 to 5, and when a reading is made, if any two of the three items, fat, specific gravity, or solids are known we can find the third. For example if the fat be known, set the arrow on the sliding scale against the amount of fat indicated on the top corresponding with what is known to be present, then observe where the specific gravity ascertained, corresponds with a line on the lowest row of divisions indicating solids; or again, suppose the solids and specific gravities are known, set the specific gravities to correspond with the known total solids, and the arrow will now mark the percentage of fat.

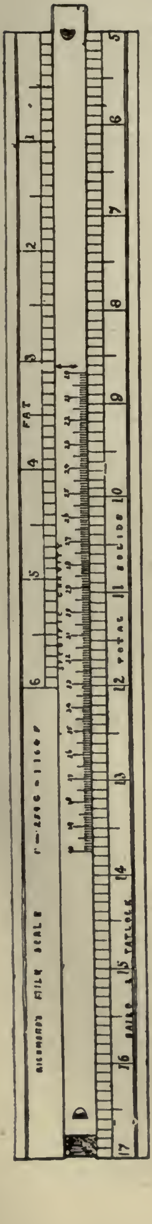

Fig. 38. Richmond's Milk Slide Rule.

It will be seen that given any two of the three items, specific gravity, percentage of fat, or solids, we can find the third. In practice specific gravity and fat are always determined, and the total solids can be found by slide rule, but it is well to determine the total solids by actual experiment, as this affords a check to other results, having found the solids experimentally, the fat found by analysis should correspond with that shown by slide rule, or having found the fat experimentally the solids, by slide rule, should correspond approximately with those shown by rule, the rule is made according to the formula, $T = \cdot 25\, G + 1\cdot 2\, F + \cdot 14$.

M. N. Gerber, in *L'Industrie Laitière*, No. 50, p. 397; No. 52, p. 413, 1892, and No. 1, p. 1; No. 6, p. 43, 1893, estimates the fat in milk by a centrifugal apparatus of his own design, he uses amyl-alcohol as in the Leffmann-Beam method, and the process, with certain modifications, can be employed for estimating the fat in milk, butter and cheese.

For milk, 10 cc milk are measured into the bottle and 1 cc of amyl-alcohol is added, and then 10 cc of strong sulphuric acid (1·820 to 1·825 specific gravity), the bottle is closed with a caoutchouc stopper, and the contents well shaken and then centrifrugalized for two to three minutes, and the percentage of fat read off when the whirling is complete.

The original Gerber apparatus was worked by handle, but the new model, which runs in ball-bearings, is so constructed that by giving from 15 to 20 sharp pulls with a string as in spinning a humming top, the apparatus is made to rotate at the rate of 2,000 revolutions per minute, and once started will run for about three minutes, at the end of which time the fat will have been completely separated out.

The Werner-Schmidt method for the estimation of fat consists in taking a known quantity of milk, separating the fat by addition of HCl, dissolving the separated fat with ether, taking an aliquot part of the etherial solution, then driving off the ether and lastly weighing the residual fat and calculating to percentage. A modification of the original process was described in the *Analyst* for April, 1867, by Mr. R. W. Woosnam, who has devised a special apparatus as figured, which consists of two parts, who describes it thus :—(*a*) A boiling flask with top, the mouth ground to fit the top of (*b*). (*b*) A graduated 100 cc burette with small tap at the side, placed preferably at about the 50 cc mark.

To make a determination, pipette 25 cc of milk into the boiling flask (*a*), and about 28 cc (roughly) of strong hydrochloric acid are added. For this purpose a 25 cc pipette, with stem sufficiently small to pass through the tap, is recommended. The flask is then placed in boiling water, and agitated frequently until the contents assume a pale brown colour. This generally occurs in about two minutes, and it is important that the action should not be allowed to proceed too far, or the sugar caramelized will be to some extent extracted by the squeous ether at the next stage.

The flask is now cooled, and 50 cc ether added. The tap with which the flask is fltted is then closed, and the whole shaken vigorously for some moments, after which it is firmly fixed into the top of the burette (*b*), the ground surface making a tight joint. After the separation of the ether layer, the tap is turned on and the liquids allowed to flow gently into the burette.

The measurement of the ether layer is next read off, and, after adjusting the levels of the liquids by manipulating the two taps of the burette, an aliquot part of the ether layer is drawn off from the side tap into a suitable weighed vessel, the ether driven off, and the fat weighed in the usual manner and calculated to percentage. For example, 10 cc of milk were treated as detailed, and all the fat was dissolved in say 28 cc of ether, 20 cc of this are pipetted off, 8 cc are seen to remain, on drawing off the ether in a tared dish the fat which remains weighs 26 grammes. All the fat in 28 cc of ether

$\therefore = 20 : 28 :: \cdot26 : x = 0\cdot364$, but 28 cc of ether contains the fat of 10 cc milk, so 28 cc × 10 contains the fat of 100 cc milk which 2·64, expressed more concisely the calculation in this example would be—

$$\frac{28 \times \cdot26 \times 10}{20} = \frac{28 \times \cdot26}{2} = 3\cdot64 \text{ p.c. fat.}$$

The Adams' method for the estimation of fat is the official method of the Society of Public Analysts. It consists of taking two strips of specially prepared, fat-free, bibulous paper, and dropping evenly over the whole extent of each piece 5 cc of milk, this is dried in the air, and then, to ensure all the water being removed, it is dried for a few minutes in the water oven, the object of the complete drying of the milk is to prevent substances other than fat being taken up by the ether in the next stage, in which the dried paper containing the fat is wound round a piece of glass rod, so as to make it into a neat coil, after which the glass rod is removed and the coil placed in the chamber of a Soxhlet extractor, after which a small weighed flask is attached to the lower part of the apparatus by means of a perfectly fitting perforated rubber stopper, the flask should be about two-thirds full of ether, i.e. containing sufficient to fill the chamber containing the paper about one-and-a-half times, the upper part of the extractor is fitted to a condensing apparatus, and the flask containing the ether has a basin of water placed beneath it, and below this basin of water is the lamp; great care must be taken to avoid all possibility of a flame coming near the ether containing flask. Very soon the ether will boil, and, by means of the arrangement of tubes, the ether vapour will be conveyed into the condenser whence it will distill into the chamber containing the paper, which it will gradually fill, when filled, the ether siphons over into the small flask, and this filling and siphoning of the extractor must be allowed to proceed about twelve times, then when it is nearly all siphoned over, the lamp is removed, the paper taken out, and the other coil containing the other 5 cc of milk inserted in its place; the same process is repeated as before, and when the ether has all been siphoned over for the last time, the coil is removed, the ether in the flask driven off, and the fat which remains is dried and weighed, the amount calculated to percentage on the weight of milk taken.

The weight of 10 cc of the milk is determined by pipetting 10 cc into a tared platinum dish and weighing. 10 cc weigh say 10·3 grammes, and the fat found weighs say 0·4 grammes, then—

$$\frac{100 \times 0\cdot4}{10.3} = \frac{40}{10\cdot3} = 3\cdot88 \text{ per cent.}$$

The amount of sugar in milk need not as a rule be determined, but if it be necessary, take 5 grammes of the milk, and dilute to 100 cc with ammonia and water, pour this mixture into a burette the nozzle of which passes through an opening in the cork closing a Pavy's flask, and add it drop by drop to 50 cc Pavy's solution which is kept boiling in a Pavy's flask, the ammonia which is driven off must be led away into a fume chamber. The process is stopped the moment that the blue colour is just discharged, and the amount of diluted milk which has been run in is noted, and the result calculated as follows—

100 cc of Pavy's solution = 0·05 grammes of glucose, $C_6 H_{12} O_6 + H_2O$ = 0·0678 grammes of lactose, or lactobiose, $C_{12} H_{22} O_{11} + H_2O$

For example—

5 grammes of milk made up to 100 cc with 50 per cent. ammonia solution were placed in a graduated burette and added to 50 cc Pavy's solution as detailed

13·89 cc of the 5 per cent. solution of milk ≐ 50 cc Pavy's soln.
27·78 cc ,, ,, ,, = 100 cc ,,

100 cc of Pavy's solution contains 0·0678 grammes lactose
27·78 cc of 5 per cent. milk = ·0678 grammes lactose,

and $\frac{27\cdot78}{20}$ amount of pure milk = ·0678 grammes of lactose

1·389 grammes of milk contains ·0678 grammes of lactose

$$\frac{100 \times \cdot0678}{1\cdot389} = \text{per cent. lactose} = 4\cdot88 \text{ per cent. lactose}$$

In an analysis of milk, the essential points are—the percentage amounts of fat, total solids and specific gravity. The Society of Public Analysts erring on the side of leniency in laying down a standard of milk, have declared that the percentage of fat to solids not fat, is as 3·0 to 8·5, though 3·84 fat, and 8·82 of solids would be more accurate, suppose that a sample of milk shows 3·0 per cent. fat, and 9 per cent. of solids not fat, it is evident that a certain percentage of fat has been removed, or solids other than fat have been added to the extent of 1·0 per cent., assuming that the analysis shows that there is nothing abnormal in the solids, then to ascertain the extent to which fat has been removed, we proceed thus—

$\frac{3\cdot0}{8\cdot5}$ × ascertained amount of solids not fat, gives the amount of fat which should be present, then if this amount is more than the amount of fat actually present, the calculation is as follows—

Let s. n. f. = solids not fat and a. f. = fat found in sample then $\frac{3{\cdot}0}{8{\cdot}5} \times$ s. n. f. = fat which should be present; call this F, then 100 × (F - a. f.) ÷ F = the percentage amount of fat originally present which has been abstracted, e.g., in the case quoted above, where the solids not fat were 9·0 per cent. and the fat was ascertained to be present to the extent of 3 per cent. then $\frac{3{\cdot}0 \times 9}{8{\cdot}5} = \frac{27}{8{\cdot}5} = 3{\cdot}17$ and $100 \times (3{\cdot}17 - 3{\cdot}0) \div 3{\cdot}17 = (100 \times 0{\cdot}17) \div 3{\cdot}17 = 5{\cdot}36$ the percentage amount of fat originally present which has been removed.

We can also assert that at least *n* per cent. of water has been added to the sample if the solids not fat are *less* than 8·5 per cent. By calculating as follows, let s. n. f. = ascertained amount of solids not fat present in the sample, then if 8·5 per cent. represent 100 per cent. normal milk, then $\frac{\text{s. n. f.} \times 100}{8{\cdot}5}$ = percentage of normal milk present, and $100 - \frac{(\text{s. n. f.} \times 100)}{8.5}$ = percentage of added water.

Example. Solids not fat in a sample are 7·93, then $\frac{7{\cdot}93 \times 100}{8{\cdot}5} = \frac{793}{8{\cdot}5}$ which = 93·29 per cent. of pure milk, or 100 — 93·29 = 6·7 per cent. of added water, or more directly as follows, $\frac{(8{\cdot}5 - \text{s. n. f.}}{8{\cdot}5} \times 100)$ which gives the percentage of added water direct in the example just given, thus—

$$\frac{(8{\cdot}5 - 7{\cdot}93 \times 100)}{8{\cdot}5} = \frac{{\cdot}57 \times 100}{8{\cdot}5} = \frac{57}{8{\cdot}5} = 6.7$$

H. Droop Richmond has recently pointed out* that much more accurate results are obtainable if we calculate the percentage of added water from the last two figures of the specific gravity of the milk taken at 60° F (water being 1,000), by adding these figures to the percentage of fat found to be present, we obtain a *constant*. The average of a long series of analyses of milk samples, known to be genuine, which have been made by different analysts shows this constant to be

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*P. 169, *Analyst*, Vol. XXIII, 1898.

36·02, or in round numbers 36·0; now if the calculation is being made for the law courts, in order to give the defendant the greatest latitude which can reasonably be allowed, the constant, resulting from the sum of G+F is assumed to be 34·5, just as when the amount of added water is being calculated from the amount of solids not fat, which are present, the limit of solids, not fat, in natural milk is assumed to be 8·5 instead of 9·0 per cent., which would be nearer the true amount.

Let 36=100 per cent. milk, then

$$\frac{36 - n \times 100}{36} = \text{percentage of added water;}$$

where n = number resulting from the sum of the ascertained specific gravity and fat in the sample in question.

Richmond made a long series of experiments, by adding a known amount of water to the milk, and then calculating the added water by the two different methods detailed above, and in 13 different experiments, of which he gives the results, it is shown that by making the calculation of added water from the sum of specific gravity and fat, in 12 cases he was nearer the truth, the average error of the series being 1·01 per cent. under the true amount, whereas by the other method the average error was 2·16 per cent. under the true amount.

It is not often necessary to estimate the proteids contained in a sample of milk,* but if it is required to do so, the nitrogen contained is determined by Kjeldahl's process, and from this the proteids are calculated by multiplying by the factor 6·33; 6·25 has been suggested as giving more accurate results, but 6·33 is the factor usually employed.

For Kjeldahl's process we require (1) a strong hard-glass flask, which is fitted with a perforated rubber cork which can be connected with a distilling apparatus, (2) a flask to act as a receiver, (3) a burette for use in titrating the acid, and the following solutions:—

$\frac{N}{10}$ Sulphuric acid or $\frac{N}{10}$ Oxalic acid
and $\frac{N}{10}$ Sodium hydrate solution

Solution of methyl-orange as an indicator. Some strong sulphuric acid, known to be free from ammonia. Strong solution of sodium hydrate, from which all traces of ammonia have been removed by boiling: Detail:—Weigh out 5

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* In legal cases in order to prove abstraction of cream, or addition of water, it is necessary to make a full analysis, several cases in which the addition of water was beyond a doubt, have been dismissed because the analyst had neglected to state the constituent parts of the sample analysed.

grammes of milk, (this is preferable to taking 5 cc and making the necessary allowance for the weight of 5 cc of milk being more than 5 grammes.) Evaporate the milk to dryness in the hard-glass flask already mentioned. Add 10 cc of the strong sulphuric acid, and ·75 grammes of red mercuric oxide, fix the flask in a slanting position over a bunsen burner, in a fume chamber, the flame being regulated so that the temperature of the acid is just below its boiling point. If it tends to become clear nothing more is added, but if after a time it is still black 5 to 10 grammes of potassium sulphate are added, and the heating is continued for from one to two hours, after which cool, and add about 200 cc of distilled water and pour into distilling flask, rinse out with more distilled water, then add carefully an excess of sodium hydrate solution until the acid is more than neutralised, connect the flask with the distilling apparatus, and commence distilling, and allow distillate to be collected in a receiver containing 40 cc of $\frac{N}{10}$ oxalic or sulphuric acid. When the greater part of the contents of the flask have distilled over, the process is stopped and the contents of the receiver are titrated with $\frac{N}{10}$ sodium hydrate, the exact strength of which has been accurately determined by titration with $\frac{N}{10}$ acid, each 1 cc of the $\frac{N}{10}$ acid placed in the receiver, which has been neutralised by the distillate $=0{\cdot}0014$ gramme of nitrogen; and the percentage of nitrogen is calculated in the manner shown by the following example :—5 grammes of milk treated by Kjeldahl's process, neutralised 20 cc of $\frac{N}{10}$ acid, there are, therefore, 20 × 0·0014 gramme of nitrogen in 5 grammes of milk.

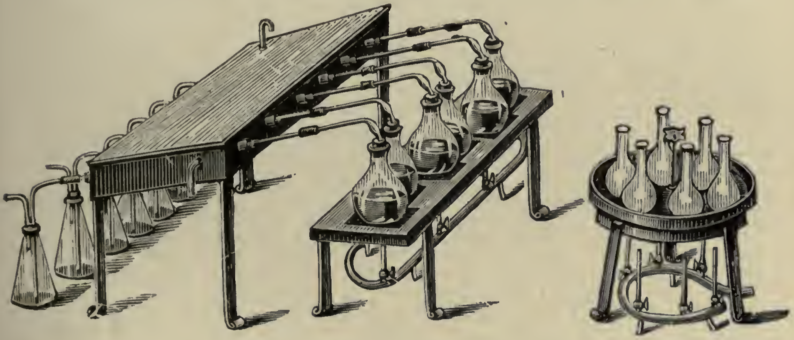

Fig. 39. Kjeldahl's Apparatus.

$$\frac{20 \times {\cdot}0014}{5} \text{ grammes nitrogen in 1 gramme of milk,}$$

$\frac{20 \times \cdot 0014 \times 100}{5}$ grammes nitrogen in 100 grammes milk : this worked out is found to be 0·56 per cent. nitrogen. Nitrogen multiplied by factor 6·33 = proteids. $0{\cdot}56 \times 6{\cdot}33 =$ 3·5448 per cent. proteids.

Diseases spread by Milk.

Disease may be conveyed through the medium of milk in two ways.

1. The secretion may be contaminated by an infected animal.

2. The milk may become infected after milking, by the addition of infected water, by washing the milk-containing vessels with infected water, or by contact with infected material or people.

Class I. includes tuberculosis, foot and mouth disease, anthrax, acute enteritis.

Class II. Typhoid fever, diphtheria, scarlet fever, cholera, diarrhœa.

Class I. Tuberculosis is, without doubt, conveyed from animals to man by the use of raw milk from tuberculous cows. *Tuberculosis is very common amongst stall-fed milch cows, especially when they suffer from over lactation†, that is to say they suffer from being drained of milk over periods far too prolonged ; other causes are, too frequent calving, and being kept in crowded ill-ventilated cow-sheds, where opportunities are not wanting for the spread of the disease from one animal to another. A very large number of milk samples have been found to contain the tubercle bacillus, but it is chiefly in those cows where there is tuberculous disease of the udder that one finds the bacillus. According to some, it is not essential for the udder to be affected in order to find it, but Dr. Martin says he never found the tubercle bacillus in milk, even when tuberculosis in the cow was extremely advanced, unless there was tuberculous disease of the udder. The surest mode of detecting tubercle bacilli is to inject the suspected milk into animals, but this means of detection is available for only a few, and reliance must be placed upon microscopical

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* Sir Richard Thorne Thorne has said " the greatest danger which man incurs of receiving the tubercular infection lies in the use of milk from tuberculous cows.

† According to Nocard, tuberculosis is rare in Paris, because cows are not allowed to be kept for more than a year before they are fattened for slaughter.—*B.M.J.*, 13th August, 1898, p. 410.

examination of the milk. For example if we (1) allow the milk to stand for 24 hours, the sediment can be examined by making cover-glass preparations, and staining with warm Ziehl's carbol-fuchsin for from two to five minutes, decolorising with 33 per cent. nitric acid, washing in water, and counter-staining with Loffler's methylene-blue, washing once more in water, drying, and mounting in xylol balsam, or (2) we may centrifugalise some of the milk, and examine the deposit as before, or (3) take about 200 cc of milk, curdle it by adding a little powdered citric acid, filter, and dissolve the precipitate collected on the filter in a solution of sodium phosphate, place the liquid thus obtained in a large test tube, add a little ether, shake for about ten minutes, decant the ether which contains the fat in solution, and centrifugalise the watery liquid and examine the deposit.

(4.) In *Practical Bacteriology* by Kanthack and Drysdale, Van Ketel's method is recommended. This consists in adding 10 cc of liquefied carbolic acid to 200 cc of the suspected milk, shaking the mixture vigorously for two to five minutes, then setting aside in a conical urine glass (protected from dust with a glass cover) for 24 hours, at the end of which a little of the sediment is removed from the deepest layer with a fine capillary pipette and films prepared by rubbing a drop between two cover glasses in the ordinary manner, after which the films are dried in the air and passed three times through the flame, stained by the Ziehl-Neelsen method as already detailed and examined with 1/12in. o. i. lens.

Lastly, if possible, inject a few cc of the milk collected under aseptic conditions, into the peritoneal cavity of a guinea-pig, tuberculosis results if the tubercle bacillus is present. In order to avoid the risk of contracting tuberculosis through the agency of milk, all milk should be sterilised or boiled. If milk be kept at a temperature of 65° C (145° F) for 30 minutes, heated to 80° C (176° F) for five minutes, or boiled for one minute, the tubercle bacillus will be destroyed. The majority of people dislike the taste of boiled milk, in which case the milk should be kept at 65° C for 30 minutes, as in that case the taste will not be appreciably altered, if the temperature does not exceed 70° C (158° F).

The question as to whether sterilised milk is suitable as an article of diet for infants has been investigated by Mr. J. K. Barton,* who divides sterilised milk into two classes, (I) completely, and (II) comparatively or temporarily sterilized milk. (I) without fresh food will eventually produce scurvy. If the

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* B.M.J. 2nd January, 1897. Page 14.

milk be over-heated or the heating be too prolonged, changes occur in the lactalbumin, by which its solubility is lessened, the fat globules also undergo a change, they tend to coalesce with each other, and with some of the insoluble albuminous matter. (II) never produces scurvy, and if the sterilization has been effected by raising the temperature of the milk to the boiling point, or within two degrees of boiling point, and kept at this temperature for from 5 to 15 minutes, is practically safe from pathogenic organisms.

Sterile milk, after exposure to air, turns as quickly if not more quickly than ordinary fresh milk. Sterile milk should be kept after sterilization at a uniform temperature of 40° F (4·45°C) in many cases of bottled "sterilised" milk which has been kept at the ordinary temperature of a room, the process of sterilization has been proved incomplete, it has sufficed to destroy, or is capable of destroying such pathogenic organisms as the bacilli of cholera, typhoid fever, or tuberculosis, but has failed to destroy the bacilli of infantile diarrhœa, a disease which is accountable for so much infantile mortality "these multiply at a comparatively high temperature, hence infantile mortality from diarrhœa is higher in the summer."* Flugge has even gone so far as to say that the sterilized milks of commerce are dangerous preparations, and that their sale ought to be stopped by the public authorities.

Foot and mouth disease has been already alluded to in Part I. p. 35, and Siegel† has described a small epidemic of foot and mouth disease clearly attributable to milk, the first case was one with symptoms of stomatitis aphthosa, the inside of the lips and tongue were ulcerated, and there was a pale rash on the body, in other cases the symptoms were stomatitis and enteritis, whilst many suffered from discharge from the ear, swelling and ulceration of the gums and looseness of the teeth, and great exhaustion. In one family where the father, and four children aged from 1¼ to 10 years, were attacked the symptoms were inflammation of the mouth, and in two cases blisters on the fingers and toes, one child showed a rash resembling measles and died from exhaustion, altogether there were fifteen cases, and it was proved that the milk had been derived originally from a farm where foot and mouth disease had broken out; the fifteenth case was of especial interest, as it occurred in a man who lived in a village where there were no cases of foot and mouth disease, but it seemed that this man had attended a fire in the village where the suspected dairy was, and had drunk milk there.

**Analyst*, page 102, Vol. XXI. 1896.

† *Journal of State Medicine*, Vol. VI., page 178.

In these cases the milk which had given rise to the outbreak was noticed to have possessed a yellowish colour and peculiar smell.

The Hendon disease. The outbreak of scarlet fever* which occurred in Marylebone in December, 1885, was undoubtedly traced to milk, but whether the milk owed its power of infection to the cows from which it was obtained, or whether it was infected by a person suffering from a mild attack of scarlet fever, is by no means certain; the evidence would seem to point strongly to the scarlet fever being of bovine origin, but that there may have been a mild and easily overlooked case of scarlet fever amongst one of the farm hands is held by many.

The history of the epidemic is this:—An outbreak of scarlet fever suddenly occurred in South Marylebone, this was reported to the Local Government Board on 18th Dec., 1885, by Mr. A. Wynter Blyth, M.O.H., South Marylebone, and was traced by him to milk supplied by a certain dairy in South Marylebone which was in turn supplied by a dairy farm at Hendon, which also supplied milk to St. Pancras, Hampstead, Hendon, and St. John's Wood, each of which places became a centre of infection, St. John's Wood being the last for reasons which will be afterwards explained. Mr. Blyth ascertained in regard to the South Marylebone milk business that it was only amongst the customers supplied with Hendon milk, and *Hendon milk alone*, that scarlatina had occurred. On December 15th, when the customers in South Marylebone stopped purchasing milk from the suspected dairy, 63 gallons of milk were returned to Hendon, and contrary to the farmer's orders were by the cowmen distributed amongst the poor of that place instead of being given to the pigs as ordered, and this was followed by an outbreak of scarlatina there. Dr. Power had in 1882 traced an epidemic of scarlet fever which occurred in the parishes of St. Gile's and St. Pancras to the milk supplied from a Surrey farm, where one of the cows had been suffering from an ailment, one of the symptoms of which was the presence of bald patches, in this epidemic no possibility of the milk having become infected from a human case was found by him; when therefore in the Hendon outbreak it was found that three newly-calved cows had been recently imported from Derbyshire† which were suffering from a vesicular disease of

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*Vide Local Government Board Reports, 1885, 1886.

† The dealer who was believed to have purchased these cows, in Derby Market, and who sold them to the Hendon farmer, resolutely refused all information whatever.

the teats, and that in all the places where milk from these cows was sent scarlet fever occurred, circumstantial evidence was very strongly in favour of a bovine origin; later on it was discovered that although St. John's Wood had been supplied all along from Hendon dairy, the milk was from a shed in which there was no cases of this affection of the teats, but before long this disease appeared also amongst these cows, after which in due course scarlet-fever broke out in St. John's Wood, here then would seem indisputable evidence in favour of the disease being of bovine origin, and when it was afterwards found that by isolating the infected cows, and only issuing milk from healthy cows, that the cases of scarlet-fever ceased to appear, Power and Klein, who were now working together, considered their case as proved. Crookshank and several others, by order of the Board of Agriculture, investigated the matter, and came to the conclusion that the disease, from which the Hendon cows were suffering, was no other than cow-pox. In Wiltshire, Crookshank investigated an epidemic said to be similar to the Hendon outbreak, and made cultures on nutrient gelatine and on agar-agar, and found the ordinary pyogenic organisms; they inoculated calves, which were afterwards found to show the post-mortem appearances as in the Power and Klein's cases viz. :—congestion of the lungs and pleural adhesions, microscopic examination of the kidneys showed glomerulo-nephritis, with infiltration of the sheath of the cortical arterioles with round cells and there were hæmorrhages. In the Wiltshire epidemic, according to Crookshank, the conditions were exactly parallel to the Hendon outbreak, excepting that " in spite of the contamination of the milk, no cases of scarlatina were found either on the farms or in the village, and there was no epidemic in the town in which the milk was distributed. * Sir George Buchanan, summing up Dr. Klein's investigations in regard to the Hendon disease, says that these showed "that subcultures made from human scarlatina, and inoculated into *recently calved cows*, can produce *in those cows*, along with other manifestations of the Hendon disease, the *characteristic ulcers on the teats*, ulcers identical in character with those obtained at the Hendon Farm, also " that subcultures, either from the human or the cow disease, have an identical property of producing in various rodents, a disease similar in its pathological manifestations to the Hendon disease of cows, and to scarlatina in the human subject."

These facts with other evidence detailed in Local Government Board Report 1887-88 " go to form a mass of evidence

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* *Bacteriology and Infective Diseases*, p. 274. 4th Edition, Edgar M Crookshank, M.B.

to show that the Hendon disease is a form, occurring in the cow, of the very disease that we call scarlatina when it occurs in the human subject."

It is quite possible, and would seem highly probable, that the disease of the teats in Wiltshire cows, referred to by Crookshank, although in many respects resembling the affection met with in the Hendon disease, was different and caused by one of the many streptococci which have been identified as distinct species.

Sheep (excepting Algerian sheep) and cattle are very susceptible to anthrax, and the milk of an animal would soon show anthrax bacilli after contracting the disease, (Chamberland and Straus) but since the disease is so rapidly fatal, and one which is recognised at once, it is a danger in milk which may be disregarded. The bacilli in anthrax appear in the blood of an affected animal in about 15 hours, and would therefore appear in the milk almost at the same time, through ruptured capillaries.

The milk from cows suffering from acute enteritis has been known to give rise to a similar disease in human beings.

Class II. Typhoid fever has been frequently shown as a milk-borne as well as a water-borne disease. In most cases where the disease has been conveyed by milk, it has been traced to washing the utensils with, or diluting the milk with typhoid infected water.

The question as to whether cows, drinking typhoid infected water, yield infected milk, has been raised. Likewise the danger of employing milk from cows fed on sewage farms, has been discussed as in the recent case at Aldershot, where, after a most careful investigation the milk was pronounced to be quite wholesome.

Diphtheria has been frequently traced to milk infected by persons suffering from the disease, and there is no doubt that many people suffer from mild attacks of diphtheria which are so mild that they are overlooked, but which are yet capable of giving rise to severe cases of diphtheria, attended with fatal consequences. There is a bovine disease known as "garget," in which the udder is inflamed, this has been thought to give rise to diphtheria in the human subject, but it has never been conclusively proved, although there is no doubt but that cases have occurred of severe sore-throat in consequence of milk, in which the only source of infection discoverable, was an affection of the udders of the cows from which the milk was supplied.

Scarlet fever is readily transmitted through the medium of milk.

Cholera has been traced to milk, which had been diluted with water from a cholera infected tank.

Diarrhœa of infants is well known to be very frequently spread by milk, and the danger of so-called sterilized milks has already been commented on.

Preservatives in milk :—Those most frequently met with in milk are formalin, borax and boric acid, Salicylic acid was at one time employed, but is now almost, if not quite unknown as a milk preservative, at any rate in England. Salicylic acid checks the action of enzymes, especially those that act upon starch.

The detection of formalin is not difficult, and for weak solutions, such as are employed in the preservation of milk, the most reliable is the test first described by Otto Hehner, which consists in diluting the milk with water in a test tube, and running strong sulphuric acid down the side of the tube, taking care to prevent mixing, so that the diluted milk floats on the acid, if formalin be present a violet ring is seen, which increases on gently shaking the tube.

Another test where there is doubt as to the presence of formalin, is as follows :—Take about 100 cc of the milk distill, collect the distillate, and add to it a drop of weak watery solution of phenol, after which on the addition of strong sulphuric acid, a bright red colour is seen.

There is a test with ammonia silver nitrate solution, which gives a dark brown or black colour after standing in the dark for some 18 to 24 hours in contact with the distillate of 100 cc milk. 2 grains per gallon of 40 per cent. formic aldehyde is easily detected by this means, and a sample would, as a rule contain more than this, the usual amount of formalin is equal to 3·652 grains per gallon of 40 per cent. CH_2O. This silver test is not often required, as the two first-mentioned tests are generally sufficient.

Borax or Boric acid may be detected by evaporating the milk to dryness, incinerating and moistening the ash with a drop of strong sulphuric acid and a little rectified spirit or alcohol, on applying a light ; a green flame indicates boric acid.

Another test consists in evaporating the milk to dryness, incinerating as before, dissolving the ash in a little hydrochloric acid, when, on dipping a piece of freshly prepared turmeric paper in the solution, a brown colour is seen if boric acid be present, which, on the addition of a drop of dilute sodium carbonate solution, turns the paper blue-black.

Salicylic acid is best detected by adding to 200 cc of milk an equal bulk of water, heating the mixture to 60° C, and 1 cc of acetic acid and an excess of mercuric nitrate, filtering, and to the filtrate adding some ether, after which, shake, allow the ether to separate, decant off the etherial solution, and drive off the ether by evaporation over a water bath; if salicylic acid be present, the dry residue will show a violet colour with ferric chloride.

The question as to whether the use of preservatives is injurious or not has received a considerable amount of attention of late, with the result that great diversity of opinion has been expressed. The general opinion is that preservatives such as formalin or boric acid, if present to a small extent, are in no way harmful; formalin, it is true, renders proteids more difficult of digestion, but on the other hand it is extremely fatal to micro-organisms even in minute amounts, which by their presence, or the presence of their products, would be very harmful.

Boric acid is, according to some authorities, a cumulative drug, which gives rise to gastro-intestinal disturbance in the form of vomiting, diarrhœa, and hæmorrhage, it acts as a depressant. Dr. McWeeney has pointed out the difficulty which the subjects of chronic kidney disease and children have in getting rid of boric acid and salicylic acids, so that if a sample contains say 0·05 per cent. of boric acid, a child taking say 2 pints of milk in the 24 hours would have to eliminate 8·75 grains of the substance, and if the milk contained 0·1 per cent. of boric acid, 17·5 grains of boric acid would have to be dealt with, now the dose of boric acid for an infant six months old should not exceed three-fifths of a grain.

On the other hand, Henry Leffmann in the *Journal of State Medicine*, for July, 1899,* says that "boric acid, in doses up to 3 grammes per day, is practically without influence upon proteid metabolism, and upon the general nutrition of the body," and further on he says, that "both borax and boric acid are rapidly eliminated from the body through the urine, 24 to 36 hours being generally sufficient for their complete removal."

Boric acid does not appear to interfere with either starch or proteid digestion, and boroglyceride appears to have but little interfering action.

Although contracts are not arranged by the Medical Officer for the supply of milk, yet the terms which should be insisted

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* Digestive ferments, with especial reference to the effects of food preservatives.

upon, should be clearly understood when a contract is given to anyone for the supply of pure milk.

1. The contractor should undertake to notify to the proper authority any cases of sickness amongst the herd supplying milk, and no milk shall be supplied from any cow that is sick, or which is being treated with medicines.

2. That any cases of sickness amongst the cows shall be notified to a duly qualified veterinary surgeon, cases of Tuberculosis to be at once separated, and doubtful cases subjected to the Turberculin test.

3. That any changes in the herd, such as additions or removals of animals, be notified to the proper authority, and in no case is the milk of a newly-calved cow to be supplied, until it is free from colostrum, and does not curdle on being boiled. No milk to be supplied from a cow, which has not been at least 24 hours under the observation of the contractors.

4. That the cow-sheds be properly ventilated, and be sufficiently large to prevent overcrowding.

The stalls for single animals to be not less than 8 ft. by 4ft. 6ins., and for two animals 8ft. by 7ft., with an air space of at least 600 cubic feet per head, with efficient means to ensure ventilation.

In measuring cubic space any height above 16ft. to be disregarded, and not taken into consideration in estimating cubic space.

5. That the milkmen and attendants be free from disease, and cleanly in their habits and person.

6. That the milk when supplied, shall show not less than 12·0 per cent. of total solids, 3·5 per cent. of which must be fat.

7. The milk must be supplied in properly cleansed churns, labelled with the date and hour of milking, the name of the farm, and be locked.

CHAPTER VIII.

BUTTER.

Butter, like milk, is not an article of naval dietary except in naval hospitals; it is a palatable and easily digested form of fat, provided it be not rancid, when it gives rise to dyspepsia. A man doing ordinary work requires nearly three ounces of fat per diem, one ounce of which may with advantage be butter. Butter being comparatively costly, various substitutes have been devised, these are sold under the name of margarine. When there is no attempt at concealment, this is perfectly legitimate, since much of the margarine is a pure fat flavoured and prepared so as to resemble butter; it is only when margarine is fraudulently supplied as butter, that exception is taken to it.

Butter consists of the fat globules of milk which have been caused to coalesce by the process of churning, and containing, as the following table shows, a certain amount of water, curd and salt. The fat globules in milk are so intimately mixed up with a proteid known as caseinogen, that a complete separation is impossible.

Good butter consists of :—

Fat	...	...	from	80	to	88 per cent.
Curd	...	...	,,	0·5	,,	3·0 ,,
Salt	...	...	,,	1·5	,,	5·0 ,,
Water	...	...	,,	8	,,	14 ,,

The fat is composed of fatty acids combined with glycerine, about 87 per cent of which are fatty acids, insoluble in hot water, consisting of about 40 per cent oleic and 47 per cent stearic acids, and about 6·7 per cent are fatty acids soluble in hot water, consisting of butyric, caproic, and to a slight extent of caprylic acid. Oleic and stearic acids are not volatile when fresh, whereas, butyric and caproic acids are volatile. In other fats, the insoluble fatty acids are present to a much greater extent, and the soluble to a much smaller extent than in butter, thus constituting an important point in determining the genuineness of a sample of butter. The taste of butter is a means of discrimination by no means to be despised, and this requires no description.

The colour of butter varies with the season (which influences the food of the cows), and may vary between a pale straw when the cows are fed on hay, and a rich golden tint when grass is plentiful, but the colour is frequently more dependent on materials added in the process of manufacture than on natural causes. In towns, anatto, a harmless vegetable colouring material is perhaps the commonest; it is soluble in alcohol, which, on evaporation to dryness, turns blue when a drop of strong sulphuric acid is added to it. In the country, saffron or carrots often furnish the requisite colouring material when the colouring is artificial.

Butter melts at between 86·9 and 97° F., usually at about 89 or 90° F., and is readily soluble in ether, whereas, other fats are less soluble, and apt to throw down a deposit.

The specific gravity taken at 100° F. varies between 0·910 and 0·914, that of water at 100° F. being 1·000. In margarine and animal fats it is never above 0·904. Specific gravity is best taken by melting the butter at 100° F. and carefully filling and weighing a specific gravity bottle, *filling* implies an absence of air bubbles.

Butter fat, when tested by the Hübl's iodine absorption test, is found to absorb much less iodine than foreign fats, it also yields a much greater amount of volatile fatty acids than any other animal fat.

Curd consists of some portion of the non-fatty part of milk, chiefly casein together with lactose, lactic acid and a certain amount of fat. When butter is heated to about 150° F. over a water bath in a beaker, after a time the fat rises and leaves beneath it a cloudy layer of curd, salts and water. In good butter, the curd should be present in very small amount, 3 per cent or under; in inferior butter this will be exceeded.

The salt consists of some of the mineral matter contained in milk-plasma, but principally of sodium chloride, added to improve the flavour and assist the butter to keep. Fresh butter contains from 0·5 to 2 per cent, and salt butter may contain 6, 8, or even 10 per cent of sodium chloride. The amount of salt may be determined by washing a weighed portion of butter with pure distilled water and titrating the washings with standard silver nitrate solution, or the residue left after drying some of the butter at 105° F. may be burnt and the ash dissolved in distilled water and titrated with standard silver nitrate solution.

Water is always present in butter, and is determined by taking 5 grammes of butter and drying in a tared platinum dish at 105° F. until the weight is constant, the loss of weight gives the amount of moisture, this should not, as a rule, exceed 12 per cent. Water is added to increase the weight, but excess of water prevents the butter from keeping.

Margarine is a term used to signify any fatty substance used as a substitute for butter, it is generally a mixture of the more-fluid portions of animal (beef or mutton) fat, with a certain amount of butter, or milk and butter added to give it a flavour of butter. Vegetable fats, such as palm and cocoa-nut oil are occasionally used, but as a rule, margarine consists chiefly of lard or fat taken from animals soon after slaughter, minced, washed and melted at a temperature not exceeding 112° F. and mixed with milk or butter as stated above.

There are several ways of determining the amount of volatile fatty acids present in a sample of butter, the Reichert method of estimating the amount of pure butter present in a sample, depends for its action upon the fact already mentioned that volatile soluble fatty acids are present to a much greater extent in butter than in other animal fats; the process is as follows :—Take some of the butter, melt it on a beaker over a water-bath, it will after a time be seen to separate into an upper stratum of clear butter-fat, below which is curd and water, if after a time the butter-fat does not become quite clear, it is filtered through a dry filter by means of a jacket funnel kept warm with hot water, or the filtering may be conducted in a water-oven kept at a sufficiently high temperature (100° F.), when the filtering is complete, 5 grammes of the clear liquid butter-fat are weighed into a tared narrow-necked flask of about 200 or 250 cc capacity, with a mark at 150 cc, to which are added 2 cc of 50 per cent. sodium hydrate solution and 10 cc of alcohol having a specific gravity 0·803 at 20° C., *i.e.*, 96 per cent. strength, the flask is next fitted with a rubber stopper through which passes a piece of narrow glass tube about 3 or 4 feet long, and the contents heated for 15 or 20 minutes on a water-bath with constant agitation, the fatty acids at the end of this stage are saponified, the rubber stopper and glass tube are removed and the alcohol driven off; when cool, 40 cc of 2·5 per cent. sulphuric acid are added, this decomposes the soap, setting free the fatty acids, distilled water is added to bring the whole up to the 150 cc mark, and the flask connected with a distilling apparatus after having previously introduced a few fragments of recently ignited pipe-stem in order to prevent bumping; the solution is gradually brought up to the boiling point and 100 cc distilled, the distillate is filtered and titrated with $\frac{N}{10}$ baryta-water, using phenolphthalein as an indicator. Mr. H. Droop Richmond, F.I.C., has kindly given me the detail for his own method of titrating the volatile acids. *Fig* 40 represents a burette for holding a standard solution of baryta, "the larger bottle is filled with the baryta solution, which is sucked over into the burette (before the tube from the top is put in position); the smaller bottle is filled loosely with sticks of caustic soda, or better with soda-lime. The only means by which air can enter the larger bottle is through the smaller one, in which it is deprived of carbonic acid, which would otherwise weaken the baryta solution, when the pinchcock on the tube connecting the burette with the larger bottle is opened, the baryta siphons over and fills the burette to the required level; the titration is performed by means of the pinchcock and jet at the bottom of the burette. The advantage of this apparatus is that all the air which finds access is freed from carbonic acid and there is only one opening to admit air."

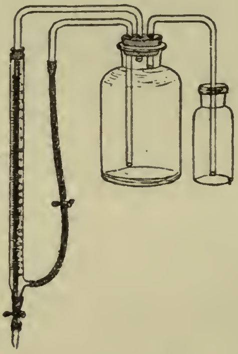

Fig. 40. Richmond's Burette with CO_2 Guard.

A. von Asboth (*Chem. Zeit.*, 1897, xxi., p. 312) has described a process for the identification of genuine butter which is quoted in the *Analyst* by F.H.L.,* who is of opinion that in determining the nature or amount of foreign fat which has been added to a sample of butter, Asboth's process, in conjunction with qualitative examination, is the most reliable test, it depends for its action on the fact that the lead salts of the soluble fatty acids are also soluble in water, whilst those of the insoluble acids are equally insoluble. Detail:—"Take 2·5 grammes of the sample and heat with 25 cc of $\frac{N}{2}$ alcoholic potash, the excess of alkali is titrated with $\frac{N}{2}$ acetic acid in order to determine the saponification number. The residual liquid is then washed into a 300 cc stoppered cylinder containing 150 cc of

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* *Analyst*, Vol. XXII., p. 213, 1897.

water, 30 cc of 10 per cent. solution of lead acetate, the whole is well shaken until the precipitate adheres together and the liquid has cleared. The precipitate is thrown on a filter of thick strong linen, and the cylinder and the precipitate washed with cold water. The lead salts of the insoluble acids are freed from moisture by squeezing them thoroughly, then removed from the cloth and put back into the cylinder, 200 cc of ether are added and the mixture shaken until the mass is completely broken up. It is rinsed into a 250 cc oil burette, excess of 1 : 4 HCl introduced and shaken until the ethereal layer becomes clear. The acid is then run off and the ether washed with water till neutral. The volume of the liquid is read, 50 cc are evaporated and dried to constant weight, and another 50 cc evaporated, dissolved in 50 cc alcohol and titrated with potash."

"Von Asboth's method for distinguishing between different fats is based on an attempt to identify each variety by the proportion of oleic acid it contains, 3 grammes of the sample are saponified in 50 cc of alcohol and 1 or 2 grammes of caustic potash. Phenolphthalein is added, and the solution neutralised with acetic acid. It is then treated with lead acetate as above and the insoluble lead soaps collected on the linen filter. The cylinder is drained from the water, the precipitate and 150 cc of ether put in, shaken up and allowed to rest over night. A funnel and a thick filter-paper large enough to hold the solution and the washings are placed in the oil burette, moistened with ether, the contents of the cylinder thrown thereon and covered with a dial-glass. The insoluble matter is washed three times with ether—using not more than 100 cc altogether—in order to make certain that the whole of the lead oleate is dissolved. The filtrate in the burette is acidified with HCl, shaken up and washed as before. The total volume of the ethereal liquid is read off, 50 cc are evaporated in a beaker on the water-bath, taken up with alcohol and titrated with decinormal acid. The amount of alkali used, multiplied by 0·0282, gives the oleic acid in the ether, whence may be found the quantity existing in the fat examined, in this manner ten different samples of butter gave 33·72 to 37·4 (mean 34); several margarine butters 45·48 to 46·0; oleo-margarine 42·61; bakers' fats 52·73 to 53·37; six lards 56·91 to 58·08; one mutton tallow 25·44; four beef tallows 33.03 to 33·95 per cent. of oleic acid respectively; it will be seen that the figures for each separate substance agree closely except in the case of butter itself (and here the variation is not serious); and the values of all the other fats are very different, with the sole exception of beef tallow, which however may be readily distinguised from genuine butter by its difference in consistency and melting-point."

The amount of iodine which a sample of butter is capable of uniting with, is a valuable indication not only of the purity of the butter, but also of the nature of foreign fats and oils when present. Fats and oils are combinations of one or more fatty acids with glycerine, the fatty acids belong to two series (1) acetic and (2) oleic, possessing widely different affinities for iodine, and according to whether fatty acids of group 1 or group 2 prevail, so the amount of iodine with which the fat is capable of combining is smaller or greater. The test employed in this determination is that known as Hübl's method of iodine absorption, in which a definite quantity of the fat under examination is placed in contact with an excess of iodine present in a solution of known strength, the solutions required are:—

1. (*a*) A solution of iodine 25 grammes in 500 cc B.P. absolute alcohol.

(*b*) A solution of mercuric chloride 30 grammes in 500 cc B.P. absolute alcohol.

Solution (*b*) is added to solution (*a*) at least 12 hours before it is required for use. The mixture being known as "Hübl's reagent."

2. A volumetric solution of sodium thiosulphate containing 24·644 grammes of $Na_2 S_2 O_3 5 H_2O$ per litre. This is made by first making a "rough" solution of sodium thiosulphate, 28 grammes to the litre, and then titrating it with $\frac{N}{10}$ iodine and starch mucilage and diluting the hypo until it is exactly equivalent to the iodine solution, the $\frac{N}{10}$ iodine solution is made by dissolving 12·59 grammes of pure iodine and 18 grammes of potassium iodide in 200 cc of distilled water, the solution being effected by constant agitation, when this is complete, distilled water is added to bring the whole up to 1 litre. 1 cc = 0·01259 gramme iodine (the $\frac{N}{10}$ iodine solution is only required for titrating the "hypo," if the $\frac{N}{10}$ iodine has been accurately prepared, and the strength of the "hypo" solution determined by it, it is not necessary for the "hypo" solution to be of exactly $\frac{N}{10}$ strength, since if we know its value in terms of iodine we can make the necessary calculations).

3. A 1:10 solution of potassium iodide.

4. Some pure chloroform.

5. Starch water; made by carefully mixing one part of of starch with 500 parts of cold water and boiling briskly for five minutes, and if necessary filtering.

Apparatus—

1. Burette graduated to $\frac{1}{10}$ cc.
2. Two stoppered flasks of 50 cc capacity.
3. Two stoppered bottles of 12 oz. capacity.

Detail.—Carefully weigh into the stoppered flask, 0·8 gramme of butter, then add 10 cc of chloroform, and 25 cc "Hübl's reagent," if clear the bottle may be closed and set aside, but if turbid a little more chloroform must be added until it is clear, the flask is then closed and placed in a moderately warm place (about 70 to 75° F) for eight hours. A control test labelled *control* is done at the same time, in precisely the same way, with chloroform and "Hübl's reagent" but no butter. After the eight hours have elapsed, add to each flask 20 cc of the 1 : 10 potassium iodide, and 50 cc of distilled water, transfer the contents to labelled 12 oz. stoppered bottles and rinse out with distilled water, and then add more water, so that with the rinsings the whole measures 150 cc, then each botlte is titrated with the "hypo," as in the Forchammer process using the starch water as an indicator.

An example will explain the calculation—

The sample required 11 cc $\frac{N}{10}$ $Na_2 S_2 O_3$ to just discharge the colour.

The control took 30 cc $\frac{N}{10}$ $Na_2 S_2 O_3$ to just discharge the colour.

The difference = 19 cc $\frac{N}{10}$ $Na_2 S_2 O_3$. Now each 1 cc $\frac{N}{10}$ $Na_2 S_2 O_3$ = 0·01259 gramme iodine, ∴ 19 cc $\frac{N}{10}$ $Na_2 S_2 O_3$ = 19 × ·01259 grammes iodine, this = 0·24 (nearly) and since we took 0·8 gramme butter—

$$\text{then } \frac{0{\cdot}24 \times 100}{0{\cdot}8} = 30{\cdot}0 \text{ per cent. iodine absorbed.}$$

The iodine absorption of butter ranges from 23 to 38 per cent.

Margarine	...	...	from 40 to 55 per cent.
*Beef fat	...	...	,, 34 ,, 45 ,,
Lard ...	...	...	,, 52 ,, 62·5 ,,
Linseed Oil	...	...	,, 173 ,, 187 ,,
Cod liver oil	...	...	,, 158·7 ,, 166·6 ,,

There are other modes for determining the purity of butter, such as the Valenta acetic acid test, Kœtstorfer's process, etc., and the reader is referred, for the details of these

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* A short Manual of Analytical Chemistry by Muter, eighth edition, 1898, Baillière, Tindall & Cox.

processes, to other works on Food Analysis, such as Muter's* or Pearmain and Moor's.*

Preservatives in butter :—

Boric acid is the commonest, and is detected in the ash as shown in the chapter on milk.

Salicylic acid may be detected, if present, by adding a strong aqueous solution of sodium bicarbonate, and adding to the extract thus obtained, which contains sodium salicylate, some dilute sulphuric acid, then extracting with ether, evaporating to dryness and adding a drop of ferric chloride, a purple violet colour is seen if salicylic acid be present.

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* Baillière, Tindall & Cox, King William Street, Strand.

CHAPTER IX.

WHEAT, FLOUR, AND STARCHES.

Flour should be prepared from wheat by the process of milling and sifting, which removes the outer coats and leaves only the central portion of the grain which consists principally of starch, but also contains between 10 and 12 per cent. of nitrogenous substances, a small percentage of fatty matter, and some sugar. There are numerous kinds of wheat grown for the production of flour in England, most of the wheats are known as red and white wheats, which are varieties of Triticum hibernum or winter wheat, and there is also another variety known as the awned or bearded wheat, which is less common. Before entering into a full description of wheaten flour it is well to know the characters of good wheat, the colour of which should not be too dark nor the furrow too deep, it should have no unpleasant smell, show no signs of disease, or the ravages of insects, and should be of good weight; a bushel of good wheat should weigh about 63 lbs. or 64 lbs., the drier the wheat the heavier it is, because wheat being very hygroscopic, swells if exposed to moisture, and therefore a smaller number of grains go to the bushel.

If a grain of wheat be soaked in water and then dissected with needle and forceps, it can be shown to possess four distinct coats surrounding a central network of cellulose containing starch grains.

The diseases likely to be met with in wheat are those due to vegetable parasites, chiefly belonging to the family of *Ustilagineæ* (the bunts or smuts), and also rust or mildew (*Puccinia graminis*)*which belongs to the order of *Æcidiomycetes;* this rust attacks during the summer the stems, leaves, and glumes of wheat, its appearance is well shown in the accompanying figure (*Fig. 41 B*) which shows numerous two-celled teleutospores borne by hyphæ threads growing out from the epidermis and sub-epidermal cells. The rust parasite is one possessing considerable interest to botanists, as it forms spores

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*A theory was broached in 1891 by Mr. N. A. Cobb and the late Mr. Sidney Olliff, which was published in Vol. II., Part II., *Agricultural Gazette*, N.S.W. That the singular immunity from rust of American wheat is due to the larva of the Hessian fly (Cecidomyia destructor) feeding on rust when obtainable in preference to the juices of plants.

of two distinct types at different seasons, in the summer, one-celled rounded reddish-brown groups of spores are formed in the situations already mentioned, and these cells are called uredo-spores, whereas the teleuto-spores here depicted grow in spring on the leaves of the barbery, this change of hosts with the season of the year, and at the same time alterations of habit, are the chief points of interest to naturalists.

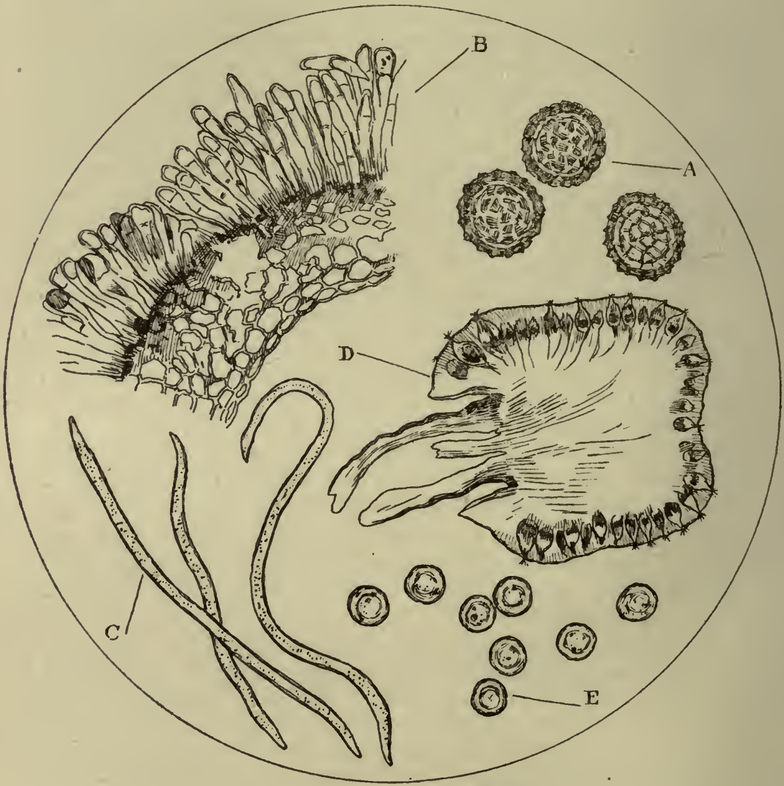

Fig. 41.—Diseases of Wheat.

Tilletia caries known also as *Uredo fœtida* or 'bunt,' (*Fig. 41, A*) attacks the interior of wheat grains and is seen as round light brown spores reticulated on the surface. "Smut" (*Fig. 41, E*) is caused by the Uredo segetum or Ustilago carbo, ears of corn attacked by it are quite black, and the interior of the grain is replaced by brown circular spores, the surface or episporium is smooth, and this under the microscope readily distinguishes it from "bunt." A sample of wheat which has been adulterated with rye, or flour prepared from grain which has been mixed with rye, may show the mycelial fungus Claviceps purpurea, (*Fig. 41, D*) which in a microscopic section is not unlike a composite flower, the circumference is seen to be packed with small flask-like bodies (*perithecia*) which are faintly purple in colour; from these flask-shaped bodies the spores are formed.

Animal parasites which attack grain are the common weevil (Calandra granaria), a small coleopterous insect which can be seen with the naked eye. The female insect makes a little round hole in the grain and deposits an egg in it, from which a larva is hatched in due course, which feeds on the contents of the grain.

Occasionally the disease known as "ear cockle" is met with in dark discoloured small-sized grains which have been kept in a damp place; under a low power objective these are seen to consist of small worms (*Anguillulæ* or *vibriones tritici*) about a $\frac{1}{40}$ to $\frac{1}{25}$ inch long. (*Fig. 41, C*).

Flour of different qualities, having distinct trade names, is met with in commerce. Thus the best flour is known as best or superfine, then come seconds or middlings, a still coarser kind is known as thirds, and lastly, we have pollards or bran flour.

The composition of flour and whole wheat is shown to be:—

	Water	*Nitrogenous Substances*	*Fat*	*Sugar*	*Gum or Dextrin*	*Starch*	*Woody Fibre*	*Ash*
Fine White Flour	13·37	10·21	0·94	2·35	3·06	69·30	0·29	0·48
Coarse Flour	12·81	12·06	1·36	1·86	4·09	65·88	0·98	0·96
Whole Wheat*	13·37	12·04	1·91	—	69·07	—	1·90	1·71

The nitrogenous substances consist of a globulin and an albumose, which when acted upon by water form gluten. A good flour should yield between eight and twelve per cent. of gluten, if there is a deficiency in the amount of gluten, or if the flour has undergone deterioration by being kept in a damp place or by being kept too long, it is impossible to use it for bread-making; much of the flour which has undergone this

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*König, i., 619, and ii., 519, quoted on p. 397 *Law and Chemistry of Food and Drugs*, by Robinson & Cribb.

deterioration to a limited extent can however be rendered usable by the addition of alum; alum then, if there were no other things against it, would be objectionable because of its rendering an inferior flour capable of being used, but, as we shall see later, there are other even graver objections to its use.

Good flour ought to be of a white or faint cream colour, should not taste acid and have no smell of mustiness; when rubbed between the hands it should feel soft and velvety, and cohere slightly when pressed together; if mineral matter has been added, or if it has been allowed to get damp it will feel gritty; it should smell sweet, and there should be no excess of bran, which would give it a brown colour.

Damp or inferior flour may contain any of the diseases previously mentioned such as vibriones tritici, and weevils; damp flour is also liable to contain meal mites (*Acarus farinæ*) which are very similar in appearance to the *Acarus scabei;* the diseases such as rust, bunt, smut and ergot should be sought for with a microscope.

If mineral matter has been added it is shown by excess of ash, (*i.e.* over two per cent.); 0·48 per cent. is given as a normal amount of ash obtainable from fine wheat flour, but some authorities give it as 1·7 per cent. on an average and 0·8 as a minimum. If the amount of ash is excessive it should be tested for carbonates, sulphates, alum, alumina or silica. Carbonates are shown by effervescence with dilute hydrochloric acid, and excess of sulphates by a heavy precipitate when barium chloride solution is added to a solution of the ash acidified with dilute hydrochloric acid. The detection of alum (*i.e.* potassium or ammonium aluminium sulphate) will be detailed later. Silica and silicates are shown by their being only slightly soluble in water after the addition of dilute hydrochloric acid and on evaporating to dryness and heating to 140° or 150° C a residue is left, which, after adding a little dilute hydrochloric acid, consists of a white gritty powder, alumina is to a slight extent naturally present combined with silica as clay, and for every part of silica present, one part of alum is deducted from the total alum found, and it is the excess of alum so found which constitutes the adulteration.

Lead should also be sought for in the ash, since a case is recorded by Alford of some millstones in which holes had appeared and which were repaired by filling them up with lead.

Mineral matter in flour may also be detected by taking about 5 grammes of the flour, shaking it up with 30 or 40 cc of chloroform in a separator or long narrow cylinder; if mineral matter be present it will sink, whereas the starches and proteids rise to the surface. The amount of moisture in good flour should not exceed 16 or, at the most, 18 per cent.; the usual amount in the best samples being between 10 and 14 per cent. of moisture. Moisture is determined by weighing a certain amount of flour, drying it at a temperature not exceeding 100° C until it attains a constant weight, the loss in weight gives the amount of moisture in the sample taken, this is then calculated to percentage. The flour, after drying, is incinerated to a white ash and the ash calculated to percentage.

Gluten is estimated by taking a certain quantity of flour, making it into a stiff dough, and then gently washing it until the water in which it is washed ceases to become turbid and shows no starch with iodine, and there remains an elastic mass (gluten) which, after being dried over a water bath or in a water oven should, on calculating to percentage amount to some 10 or 12 per cent.

Ergot in flour may be detected (*i.*) by the smell of trimethylamine which arises when a solution of caustic potash is mixen with ergotised flour. (*ii.*) By adding to the above test dilute nitric acid until it is slightly acid, and then once more adding dilute caustic potash solution until it is neutral, when a violet colour appears. (*iii.*) Another test is to take 2 grammes of flour, add 10 cc of 70 per cent. alcohol, and then some 5 per cent. hydrochloric acid, an orange-yellow colour will now be seen if ergot be present. But there are other things such as the weed corn-cockle (*Agrostemma githago*), *Lolium;* or beans, all of which also show this reaction. A saponin derived from corn cockle (*Agrostemma githago*) known as *agrostemma-sapotoxin* has been described by R. Kobert (Chem. Centr. 1893 i. 32) the formula for which is $C_{17}H_{26}O_{10}$ (Alfred H. Allen, *Commercial Organic Analysis*, Vol. iii, Part iii, p. 123). This substance is absorbed by the subcutaneous tissue, and the large intestines, the symptoms of poisoning by it are, intense muscular weakness, increase in the rate of respiration, and finally death from asphyxia; after death, fulness on the right side of the heart and intense congestion of the intestines are seen. *Lolium temulentum* or Darnel is a grass belonging to the tribe *Hordeæ,* it sometimes grows to a dangerous extent amongst wheat, and so may be gathered with the wheat and ground up with it; it has a poisonous action if present to any appreciable extent, and gives rise to a burning pain in the throat, nausea and vomiting, drowsiness, vertigo, and occasionally staggering gait, convulsions, and hallucinations, have been observed; it is detected by making an alcoholic extract of the suspected flour, which, if lolium be present will be coloured greenish, and have a disagreeable taste not found in an alcoholic extract of good wheat flour free from lolium.

Other vegetable adulterants consist of barley, rye, bean, pea, potato, maize, oats and rice, these would not probably be added in times of plenty, they are not actually harmful, but for the most part less nutritious than wheat, the leguminosæ excepted, and these adulterations would tend to spoil the appearance of the bread. Maize under certain circumstances, may be actually harmful, for example, the employment of maize that has undergone partial decomposition is very objectionable, for during decomposition two distinct poisons are developed, one being a narcotic and the other a muscular excitant producing spasmodic contractions, and again, maize that has become diseased (verdet) produces a disease resembling ergotism in many ways, which has been known for numbers of years in Italy as pellagra (*pellis,* a skin or hide, and *Gr: agra* seizure). The skin affection was formerly the symptom chiefly considered, but it is now known that grave nervous disorders are connected with the disease such as melancholia with suicidal tendencies, and there are also spasmodic contractions of various muscles, and gastro-intestinal disturbance. The various foreign meals are recognised by the starches they contain.

Starch granules are composed of two substances, granulose and erythro-granulose enclosed in an envelope of starch-cellulose, the granulose is soluble in dilute mineral acids and saliva, and coloured blue with iodine, the cellulose is not dissolved by the acid, and is coloured brown with iodine; by boiling, the contents of the cells swell, burst the enclosing walls and are set free as "soluble" starch; starch grains are as a rule more or less laminated, the markings which appear as a result range more or less around a certain point variously shaped in the different grains, this point being known as the hilum. The shape of the starch grains, the markings, position and appearance of the hilum, are the points upon which we depend for the identification of the species.

Starch grains in general, as well as those of the particular grains liable to be be met with in adulterated flour will now be described. They may be divided into two principal classes—

1. Those with an even contour.
2. Those with an irregular or facetted outline.

Group 1. may be sub-divided into—

(*a*) Round or oval granules without any markings or hilum (barley and wheat), *Figs. 42, 43,* or with a starred hilum (rye). *Fig. 44.*

(*b*) Irregularly oval or oyster-shell shaped with distinct concentric markings and a well-defined hilum at one or other end (Potato, Arrowroots) *Fig. 45.*

(*c*) Oval kidney shaped granules, with faint concentric markings and a linear hilum—starches of leguminous plants such as peas and beans. *Figs. 46, 47.*

Group 2. is sub-divided into—

(*a*) Facetted grains (maize, oatmeal and rice). *Figs. 48, 49, 50.*

(*b*) Irregularly facetted or truncated, *i.e.*, like irregular logs with the branches lopped off (sago and tapioca). *Figs. 51, 52.*

The various starches may be arranged according to size and their distinguishing marks—

Potato grains are as a rule large, they vary from $\frac{1}{40}$ to $\frac{1}{200}$ of an inch in their longest diameter, the large cells predominating, and the hilum is as a rule at the smaller end. In arrowroot the grains are for the most part smaller than those of potato, except in the case of *tous-les-mois* arrowroot, which are larger, and have the hilum at the large end.

Sago grains, irregularly truncated and many flask shaped cells.

Bean and pea. Bean starch is usually somewhat larger than that of pea, and the hilum is more irregular.

Rye consists of large and small circular cells, (*Fig. 44*) some of the larger ones having a star shaped hilum, wheat and barley (*Figs. 42, 43*) circular and without hilum, the former consisting chiefly of very large and very small size granules, whereas the latter shows many of medium size. Tapioca grains (*Fig. 52*) are small, they are irregular in shape, show many goblet shaped cells somewhat smaller than those of sago, (*Fig. 51*) and also have a more or less circular hilum.

Maize are very characteristic polygonal cells, with well-marked star shaped hilum. *Fig. 48.*

Oats are angular cells tending to adhere together in rounded masses. *Fig. 49.*

Rice are small angular cells often seen to be grouped in twos and threes. *Fig. 50.*

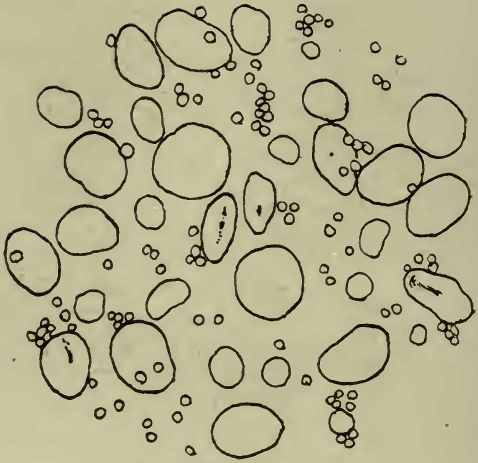

Fig. 42. Wheat Starch. × 400.

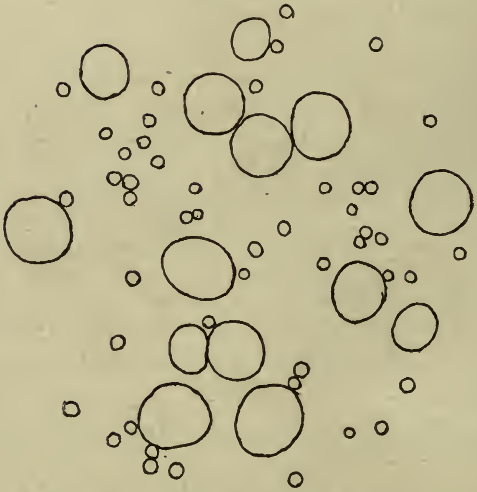

Fig. 43. Barley Starch. × 400.

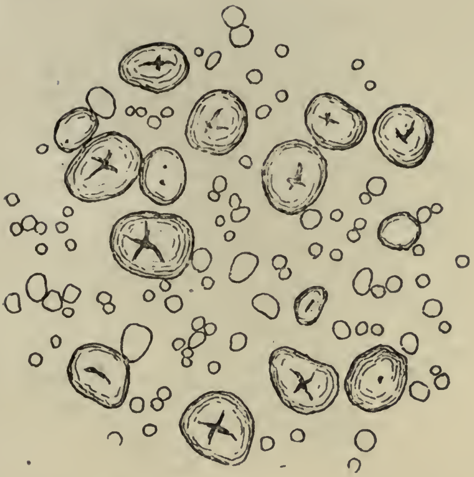

Fig. 44. Rye Starch. × 400.

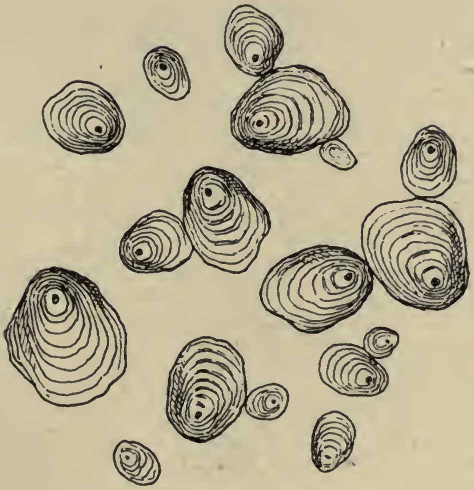

Fig. 45. Potato Starch. × 300.

Fig. 46. Pea Starch. × 300.

Fig. 47. Bean Starch. × 300.

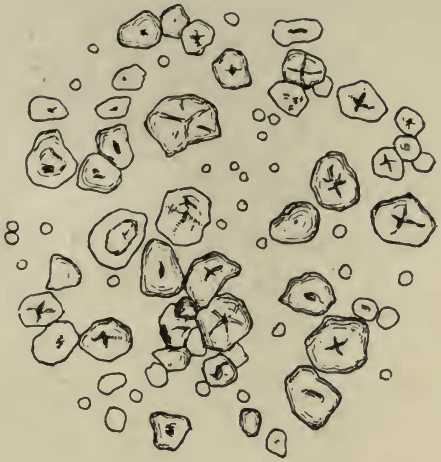

Fig 48. Maize Starch. × 400.

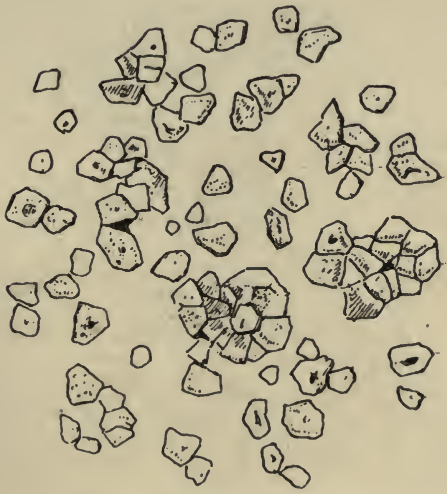

Fig 49. Oatmeal Starch × 400

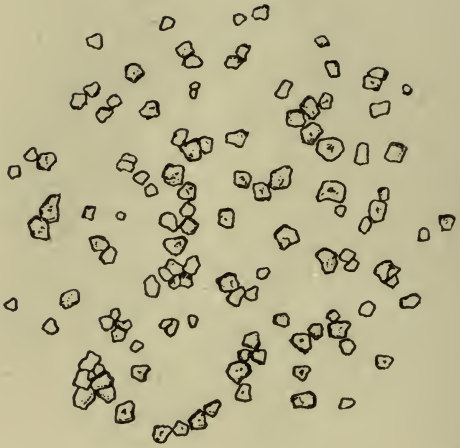

Fig 50. RICE STARCH. × 400.

Fig. 51. SAGO STARCH. x 400.

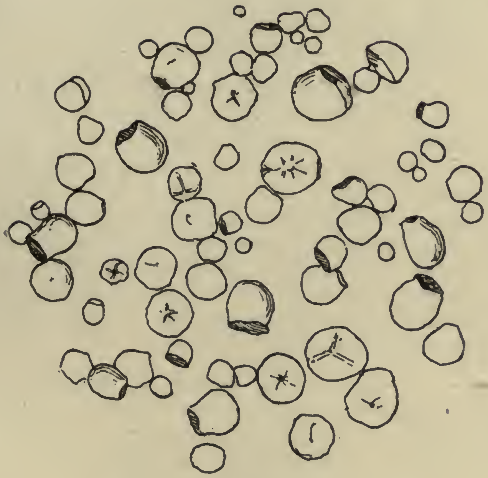

Fig. 52. Tapioca Starch. × 400.

CHAPTER X.

BREAD AND BISCUIT.

Bread should be made from the finest wheaten flour. Long experience has shown that the advantages which were at one time supposed to accrue from the use of whole-meal are more than counterbalanced by the irritating effects on the bowels, caused by the bran particles it contains.

Bread should be well-baked, show between 20 and 30 per cent. of crust, which should be firm but not burnt, the crumb should be aërated, not unduly moist, show no evidence of moulds, (*Figs. 53 and 54*) and not taste sour when eaten. The crust should always be estimated when reporting on a sample of bread. To do this, the loaf is first weighed, then carefully pared with a sharp knife, taking care to remove all the crust but none of the crumb, it is again weighed and the loss in weight gives the amount of crust, the crust and crumb are then calculated to percentage and in all subsequent tests a proportionate amount of each is taken.

Moisture is estimated by taking 10 grammes of bread (with a due proportion of crust as noted) and drying in a water-oven or air-bath at a temperature of 90° C. for at least three or four hours. The loss of weight gives the amount of moisture, which is calculated to percentage.

Bread contracts are always made in such a way that the loaves, after being well and properly baked, shall, as required, weigh 4 lbs., 3 lbs., 2 lbs., or 1 lb. each respectively *at the time* of delivery, such time to be within 24 hours, but not sooner than 12 hours after being baked.

The loss from evaporation in bread amounts to 8 per cent. in one day and about 14 per cent. in seven days. Bread which has been baked over 48 hours commences to taste stale, this is in a great measure, but not entirely, attributable to loss of moisture, since by moistening it and re-baking, the bread is restored to its former freshness for a little while, but then quickly becomes stale, staleness is in part due to changes in the bread brought about by micro-organisms and moulds.

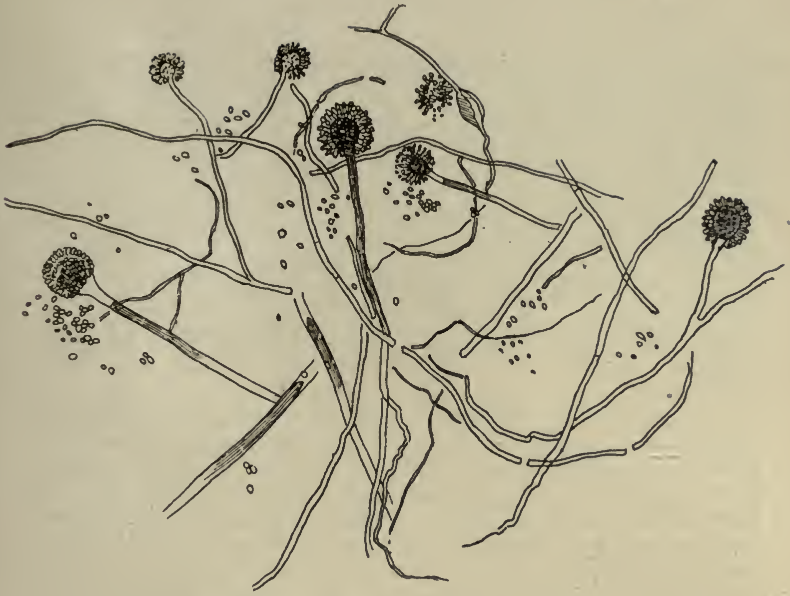

Fig. 53. Aspergillus Glaucus. × 240.

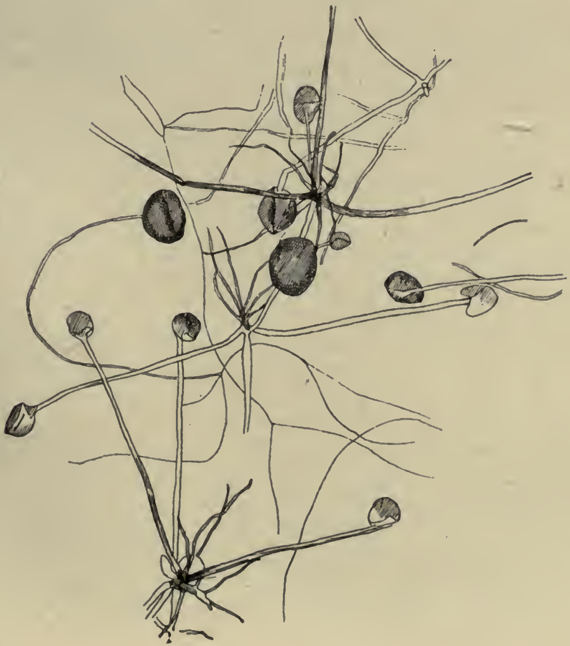

Fig. 54. Mucor Mucedo. × 240.

Having calculated the moisture, the dried bread is burned at a low red heat until it consists of a charred mass, this is then pounded in a mortar, taking care to avoid any loss, and returned to the platinum dish and burned to a white ash, the ash should be slightly over 1 per cent. and under 3 per cent., but I have examined many good samples of bread showing amounts of ash varying between 0·75 and 1·5 per cent.; if the ash be strongly alkaline in reaction it shows that excess of potato has been used in the process of "feeding the ferment," or in some other stage of bread making, except in the case where the bread itself is alkaline, in which case the alkalinity is due to sodium carbonate added in the process of bread making.

Acidity is estimated by taking 10 grammes of bread (including a due proportion of crust), macerating it for one hour with distilled water, straining or pouring off the clear fluid, and titrating with deci-normal soda, not more than 1 cc of this should be necessary, and the best indicator is delicate litmus paper, phenolphthalein or methyl orange are not sufficiently sensitive.

1 cc of $\frac{N}{10}$ NaHO = 0·006 gramme of glacial acetic acid ($HC_2H_3O_2$), this is calculated to percentage and to grains per lb. A good bread will, as a rule, show on an average about 3·5 to 5·0 grains per lb. of $HC_2H_3O_2$, but a bread need not be condemned as sour unless it exceeds 12 grains per lb., which should be the extreme limit.

Example: 10 grammes of bread treated as directed contained acid equivalent to 0·9 cc of $\frac{N}{10}$ NaHO, *i.e.*, = 0·9 × 0·006 gramme $HC_2H_3O_2$ = 0·0054 $HC_2H_3O_2$ for 10 grammes, which is the same as 0·054 per cent. acetic acid. Since there are 7000 grains in 1 lb. if we multiply the percentage amount by 70, it gives the answer in grains per lb. in this case equal to 3·78 grains per lb. of glacial acetic acid.

Where greater accuracy is required 20 grammes of bread are taken and placed in a wide-mouthed stoppered bottle containing 200 cc of rectified spirit, the bottle is then closed and left for some hours, when 100 cc of the clear spirit are decanted and titrated as before mentioned.

Alum. The advantages of alum from a baker's aspect are that by its use an inferior and otherwise useless flour can be employed, since alum prevents fermentative change, resulting in the production of diastase, which is an albuminous substance of an unknown composition produced in the process of germination, this diastase is an enzyme and is capable of transforming starch into maltose and dextrine, the diastase is produced at the expense of the nitrogenous substances in flour and gives the bread a sweetish, dark, and unpleasant appearance. Alum also helps to make the bread light and of a good colour; it is used in inferior baking powders chiefly on account of cheapness. From a health point of view alum cannot be too strongly deprecated, as it renders the nitrogenous substances in flour indigestible, interferes with all the digestive processes, forms insoluble salts with phosphates, and may, if used in baking powders with water and soda, act as a purgative through the formation of sulphates of soda, and if potash alum $Al_2 (SO_4)_3 K_2 SO_4 24H_2O$ be the one employed, then $K_2 SO_4$ may be set free, which acts as mild purgative, the dose of which is from 10 to 40 grains.

Alum is detected in bread by making a fresh tincture of logwood chips (5 grammes) with 70 per cent. alcohol (100 cc) also a 15 per cent. solution ammonium carbonate. A drachm of each of these added to a wineglassful of water and poured over a slice of the suspected bread, turns it a rose-pink colour which soon turns to a lavender-purple colour if alum be present, and persists for at least 24 hours, whereas if no alum be present the bread soon turns brown; in this colour test alum plays the part of a mordant.

If the logwood test shows a persistent mauve colour on drying for say 12 or more hours then it is advisable to make a quantitative estimation, this is best done by the method detailed in *Muter's Manual of Analytical Chemistry*, 8th edition, p. 180., in which it is advised to take 100 grammes of bread, reduce to a white ash, then add 5 cc of fuming HCl, cover with a glass plate and leave it for 15 minutes, then add 25 cc of distilled water, and boil gently for five minutes, after which filter. The insoluble matter (clay and silicious matter) is washed, the washings added to the filtrate, and the latter mixed with 5cc of strong liquor ammonia and 40 cc of acetic acid. Since the ash of bread contains much phosphoric acid, the precipitate will consist of aluminium phosphate with some ferric phosphate, the precipitate is filtered off, washed, dried and ignited. If the amount obtained now, does not exceed 5 milligrammes, there is no need to proceed further, as the alum could only be present in small quantity, but if it does exceed 5 milligrammes, the amount of iron present must be determined, and subtracted from the total amount of precipitate, each milligramme remaining after this, being considered as 1 grain of alum per 1lb. loaf. It is generally allowed that ordinary flour contains, normally, about 0·042 per cent. of phosphate of alumina, so that this amount reckoned as alumina must be deducted from the total amount of alumina found. When alum $Al_2(SO_4)_3(NH_4)_2SO_4, 24H_2O$ is added to bread, *i.e.* when bread is adulterated with alum it is usually to the extent of 5 to 10 grains per lb.

Sulphate of copper is not known to be used as an adulterant in England, though it is generally believed to be used in small amounts on the Continent, a few drops of Potassium Ferrocyanide placed upon a slice of bread containing copper gives a reddish brown colour.

Biscuit has, from time immemorial, been the substitute for bread at sea, for the reason that bread will not keep long, as apart from loss of moisture, it develops a disagreeable taste characteristic of staleness. Biscuit contains very much less moisture than bread, and not being prepared by any fermentative process does not become stale; if kept from the effects of damp and insects, it will keep good for 6 or 7 years or possibly longer, and only requires to be re-baked to make it crisp and fit for use.

At one time biscuit was kept in sacks, which afforded no protection against rats, insects and damp, later it was packed in casks, and at the present time it is sent out in hermetically sealed tins, protected from injury and variations in temperature by an outer casing of wood. The weight of biscuits supplied to the Royal Navy must be such that not less than five go to a pound, they are hexagonal in shape; when biscuits are cut square or hexagonal, the waste, which is unavoidable with circular biscuits, is avoided. Biscuit is made by mixing flour and water into a firm paste, which is rolled by steam rollers, cut by a stamping machine, baked in a quick oven and finally dried in a hot drying loft, and when quite dry, packed in tin-lined cases, which when filled, are hermetically sealed.

Biscuit should be of a light brown colour, not burnt, the outer surface should be firmly adherent to the part beneath, it should be dry, give a ringing sound when struck, be readily broken in the hand, not fall to dust, the broken portions should be somewhat flaky, free from discoloration, have no unpleasant odour or mouldy taste, should be readily dissolved by the saliva, and pieces of it should float in water, and show no evidence of insects. When baked in an oven for a few minutes at a temperature of about 212° F, biscuit should become crisp and palatable. Although bulk for bulk biscuit contains more nitrogenous matter and more carbohydrates than bread, it is less nutritious, the great variety in taste of different breads is lacking in biscuit, so that one is apt to tire of biscuit. Navy biscuit analysed by me at Haslar, showed the following percentage composition—

Moisture	*Proteids*	*Carbohydrates cellulose & fat (by difference)*	*Salts*
9·69	10·91	78·4	1·0

The percentage composition of Navy biscuit according to Dr. Church is—

Moisture	*Proteids*	*Fat*	*Starch and Dextrine*	*Cellulose*	*Salts*
10·20	10·90	1·60	75·00	1·20	1·10

CHAPTER XI.

LIME JUICE.

Lime juice was, on the recommendation of Sir Gilbert Blane, introduced experimentally into the Royal Navy as a remedy against the ravages of scurvy* in 1795, although Woodall had advised its use as a remedy against scurvy as early as 1617. In 1796 it was issued to all ships, and we are told that within one year after its introduction scurvy had become an extinct disease. Lime and lemon juice supply potash to the blood in a form which can be assimilated; potash salts in which the acid radicle is a mineral one, or citric acid alone, have little or no anti-scorbutic action, but when citric acid or citrates of potash are employed in the form in which they are met with in such juices as those of the lemon or lime, then the action is seen at its best, the citric and other vegetable acids become changed in the blood into carbonates; the ash of plants, or ash resulting from the incineration of vegetable juices like those of the lemon or lime, are likewise alkaline from a similar cause. Scurvy appears when there is a deficiency of potash salts in the blood which gives rise to hæmolysis since the principal salts of the red blood corpuscles are those of potash; this deficiency is generally caused by a want of a proper proportion or an absence of fresh vegetables or fresh meat. When salt meats and preserved foods form the sole dietary there is a deficiency in potash and an increase in the amount of potash excreted, in other words there is a reduced income and an increased expenditure, the latter being due to the ingestion of sodium chloride which tends to cause a greater loss of potash than occurs at such times when salted provisions are not the principal foods. Whether or not scurvy is a disease of microbic origin as has been stated, there is no doubt but that the disease only exists amongst those who have been deprived of their daily quota of potassium in such form that it may be assimilated, and the blood in these cases has in consequence become profoundly altered; if the disease be due to a microbe, the altered condition would explain how the blood has been rendered incapable of resisting the specific organism credited with the causation of scurvy by certain pathologists.

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* The mortality from scurvy in 1780, according to Sir Gilbert Blane, amounted to one in seven of a force of 7000 to 8000 men employed in the West Indies.

Lime juice is the expressed juice of the Citrus limetta, fortified by the addition of about 1 ounce of brandy to each 10 ounces of juice.

Samples which I have examined at various times show as a rule the following:—

Grains per ounce citric acid $H_3C_6H_5O_7$	Sp. Gr. at 60° F. as issued.	Per cent.		
		Alcohol, vols.	Total solids.	Ash.
23 or 24 up to 27	1·022	4 or 5	8 to 8·5	0·28 to 0·45

The examination is conducted as follows:—Into a tall glass cylinder pour out some of the lime juice, note the smell, taste, colour, and appearance; the odour should be agreeable, the taste palatable and sharp, but not bitter, the colour that of amber, and the fluid should be clear and free from stringiness or deposit. Specific gravity is taken at 60° F., preferably with a Westphal's balance, but a urinometer will answer sufficiently well for rough purposes, the specific gravity should be about 1·022 or 1·023. To determine the amount of alcohol present the lime juice is now evaporated to half, and then made up to the original volume with distilled water, and the specific gravity again taken at 60°F.; if now we subtract the first specific gravity from the second specific gravity and subtract this number from 1000, we can on reference to the alcohol table on p. 202, read off the amount of alcohol present.

Free acidity is determined by taking 1 cc of the lime juice, adding about 20 cc of water, and titrating with $\frac{N}{10}$ NaHO, using phenolphthalein as an indicator; each 1 cc of the $\frac{N}{10}$ NaHO used equals 0·007 gramme of citric acid $H_3C_6H_5O_7H_2O_1$ or $C_3H_4(OH)(COOH)_3H_2O$, the amount thus found multiplied by 100 gives the percentage amount, and this percentage amount multiplied by 4·375 gives grains per ounce. If it is required to determine the citric and other combined acids, the reader is referred to Pearmain & Moor's *Analysis of Food and Drugs* (Baillière & Co.).

The ash should be alkaline, it is therefore dissolved in water and the reaction taken. In some lime juice tested by me the alkalinity of the ash was equal to 0·145 per cent. KHO. Adulterants :— The lime juice may be purely factitious and made up of citric acid (generally about 7 or 8 grains per ounce) and flavouring agents, in which case on evaporating there will not be any characteristic aroma.

Sulphuric acid is detected by the barium chloride test as described under water tests, and can be estimated by Hehner's method, which consists in evaporating to dryness 50 cc of the lime juice together with 25 cc $\frac{N}{10}$ NaHO in a platinum dish, igniting to a white ash, then adding 25 cc $\frac{N}{10}$ HCl to neutralise the $\frac{N}{10}$ NaHO previously added; if now we heat to expel CO_2, filter and wash the filter with warm water and the washings mixed with the filtrate, on titrating with $\frac{N}{10}$ NaHO and phenolphthalein, the amount required to neutralise the solution is proportional to the amount of sulphuric acid present, the number of cc $\frac{N}{10}$ NaHO multiplied by 0·0049 gives the amount of free sulphuric acid in 50 cc of the sample, and this multiplied by 2 gives percentage.

Hydrochloric and nitric acid can be detected as in the qualitative water tests.

Tartaric acid $C_2H_2(OH)_2(COOH)_2$ $(H_2C_4H_4O_6)$ is detected by adding to some of the lime juice diluted to half, some acetate of potash solution, this is mixed well and set aside to stand for 24 hours, after which, if tartaric acid was present, the crystals of acid tartrate of potash $KHC_4H_4O_6$ will have fallen, these are small rhombic crystals only sparingly soluble in water.

Lime juice is issued on board ship after the ship's company has been 10 days on salt provisions, half-ounce of lime juice and half-ounce of sugar to everyone. In the tropics the engine-room department receive double the quantity of sugar and lime juice.

CHAPTER XII.

COCOA, TEA, AND COFFEE.

Cocoa is prepared from the seeds of the cocoa-palm (*Cacao theobroma*), and several plants of the natural order *Byttneriaceæ.* It is obtained chiefly from the West Indies, Venezuela, and Ecuador. That from Venezuela being the most esteemed, after which comes that from the West Indies

It is issued to the Navy in the form of chocolate, and forms a most valuable article of diet. The Naval chocolate is divided into two kinds, ordinary and soluble, both are made from the same description of seeds, which when prepared as described below, are mixed in the following proportions:—

One-sixth to one-fifth of Grenada cocoa beans.
One-fifth to one-third of Guayaquil cocoa beans.
One-half to three-fifths of Trinidad cocoa beans.

The cocoa in the above proportions is finely ground and mixed with one-fourth or one-fifth of its weight of raw sugar, forming *ordinary* chocolate, and when mixed with a slightly larger proportion of granulated refined sugar and one-fourth of its weight of arrowroot or sago-flour, forms the *soluble* variety.

Ordinary chocolate is packed for the Navy in cases of 50 lbs. or 100 lbs. capacity. Soluble chocolate is packed in cases holding 25 lbs.

In the natural state cocoa seeds are contained in pods, having an elliptical-ovoid shape, from 7 to 10 inches in length and 3 to 4½ inches in diameter, each fruit contains from 20 to 40 or more seeds.

The pods when ripe are either buried in the earth until the pulp becomes rotten, or else allowed to undergo a process of fermentation for five days in earthen jars, in order to separate the seeds from the pulp. Those which have been buried are said to yield the best cocoa. The seeds are about the size of an almond, and according to Payen have the following percentage composition:—

Fat (cocoa butter)	52·0
Nitrogenous compounds	20·0
Starch	10·0
Cellulose	2·0
Theobromine	2·0
Salts (consisting largely of phosphates)	4·0
Moisture	10·0
Cocoa-red, and essential oil ...	Traces
	100·0

The seeds, after they have separated from the pulp, are picked out and dried in the sun or in ovens, after which they are roasted in iron cylinders at a temperature of from 500 to 600 degrees Fahrenheit, the temperature being regulated according to the variety and quality of the cocoa beans; roasting develops the aroma and flavour, and when complete the cocoa is allowed to cool on the floors for about 12 hours, after which it is slightly crushed and shelled, then winnowed and sifted in order to prevent loss from portions of the nibs adhering to the husk.

A substance possessing a composition such as that shown above should be both nourishing and stimulating, and such it undoubtedly is. In the chocolate supplied to the Navy none of the fat is removed, this accounts for the oil which is seen on the surface of the boiled chocolate issued from the galley on board ship, the excess of fat in most of the cocoas and chocolates met with in commerce is removed, and in some cases saponified by alkalies. The use of alkalies is a practice to be deprecated, and has arisen from the dislike which many consumers have to greasy cocoas.

Theobromine which is contained in cocoa is a powerful alkaloid, having the chemical formula $C_5 H_2 (CH_3)_2 N_2 O_4$ or $C_7 H_8 N_4 O_2$, a homologue of caffeine. $C_8 H_{10} N_4 O_2$.

Prepared cocoa contains from 1·3 to 1·7 per cent. theobromine. Coffee from 0·8 to 1·0 per cent. caffeine.

In the examination of chocolate an important point to observe is whether or not it has been attacked by the larvæ of the chocolate moth Ephestia elutella; these honeycomb the chocolate and spin webs over it, and in consequence careful precautions to prevent the ravages of the chocolate moth are taken by Admiralty authority, no chocolate being allowed to be stored in the same building as that in which the process of manufacture is going on, as soon as the chocolate is packed in the cases lined with tin-foil, these are thoroughly lime-washed externally and removed into store.

The analysis of cocoa or chocolate would not often be necessary. The following is the approximate percentage composition :—

Navy ordinary Chocolate.	
Water ...	2·25 to 3·0
Fat ...	45·50 to 46·0
Ash ...	3·0
Cellulose ...	3·0
Nitrogenous matter including Theobromine	17 to 18·25
Starch ...	8·00
Sugar ...	20·00
	100·00

Navy soluble Chocolate.	
Water ...	4·5
Fat ...	33·4
Ash ...	2·0
Cellulose ...	2·0
Nitrogenous matter including Theobromine	5·1
Starch ...	28·0
Sugar ...	25·0
	100·0

Theobromine which contains 31·1 per cent. nitrogen (Pearmain & Moor) is estimated by drying a given quantity of chocolate and extracting it with petroleum ether which dissolves the fat, sugar, theobromine, etc. ; this extract is dried at 100° C. over a water bath to remove the petroleum ether, and the residue extracted with alcohol of 78 per cent. strength, this dissolves amongst other things the theobromine, the alcohol is then driven off by drying the alcoholic extract over a water bath, and the residue dissolved in water and clarified with lead acetate solution, the lead being subsequently removed by passing a stream of sulphuretted hydrogen through the solution ; the theobromine is then obtained from the liquid by adding chloroform and shaking the whole repeatedly in a separator, the layer containing the chloroform is drawn off, the chloroform evaporated, and the residue consisting of theobromine weighed and calculated to percentage.

The *fat* is estimated by extracting a given quantity of chocolate with petroleum ether, filtering and weighing the residue from the dried filtrate, and calculating to percentage.

Ash. The residue left after extracting the fat is burnt and the ash weighed ; this should amount to 3 or 2 per cent., according to whether the sample be one of ordinary Navy or soluble Navy chocolate ; pure cocoa should yield about 5 per cent. ash.

Soluble Extract. 5 grammes of chocolate are rubbed up in a mortar with 250 cc of water until a perfect emulsion results, this is well shaken in a separator and allowed to stand for 10 or 12 hours, after which the thick undissolved portion is removed and the clear supernatant fluid obtained and filtered, a portion of this forming an aliquot part of the whole, (say 50 cc) is evaporated to dryness in a tared platinum dish and the dried extract weighed and calculated to percentage, the cold water extract in the case of *cocoa* (not chocolate) samples should not, according to Pearmain & Moor, exceed 18 per cent., who say that "any material excess beyond this will probably be due to added sugar."*

The residue left after performing the above determination is burnt, and the ash calculated to percentage shows the amount of soluble ash, which in ordinary cocoas should not fall below 2·0 per cent.†

TEA.

Tea consists of the dried leaves of *Camellia theifera* or *sinensis* (*Thea sinensis*); natural order, *Ternströmiaceæ.* On the market there are two principal kinds of tea, viz., green and black, the difference in colour being due to the mode of preparation, the green tea being dried rapidly and the black tea slowly, so that a form of fermentation occurs and the leaves turn black. Various leaves have been employed from time to time for the purpose of falsification, the leaves of hawthorn, elm, oak, poplar, sloe, elder, and beech have all been met with in samples, these are readily detected by spreading out the leaves on microscopic slides after an infusion of the so-called tea has been made; the leaves of the tea plant are lanceolate in shape and from 1½ to 2 inches in length, and about ½ inch to ¾ inch wide at the broadest part; on holding up the leaf to the light the venation is seen which is quite characteristic; the veins run out from the midrib nearly to the border and then curve slightly forwards and inwards, the veins of leaves other than tea being continued to the edge. The leaves which bear most resemblance to tea leaves are those of the willow and sloe. Willow leaves are longer and narrower, and the serrations are coarser and shallower; the sloe leaves are more deeply serrated, and the leaf is broader and more ovate. Tea leaves which had been previously infused were at one time faced with a mixture of Prussian blue, turmeric, and calcium sulphate, and when dried and rolled, sold as green tea; others faced with black lead, dried and rolled, being passed off as black tea. The detection of exhausted leaves is most easily accomplished in the ash as detailed below, exhausted leaves yielding much less soluble ash than those which have not been used.

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*[*Aids to the Analysis of Foods and Drugs*, by T. H. Pearmain & C. G. Moor London—Baillière, Tindall, & Cox.

† *Ibid.*, p. 87, 2nd edition.

The following table shows the percentage of the chief constituents of dry tea:—

Caffeine.	Tannin.	Cellulose.	Total Ash.	Soluble Ash.	Water.
1·8 to 3·5	12 to 15	20 to 22	5·4 to 7	2·8 to 4	4 to 11

As far as we are concerned it will suffice to estimate the moisture, total ash, and the soluble ash.

Moisture is determined by drying 5 grammes to a constant weight and calculating to percentage.

The *total ash* is found by incinerating the dried tea at as low a temperature as possible, if this amounts to more than 8 per cent. it shows mineral adulteration.

The *soluble ash* is found by pouring boiling water on the total ash and filtering, the ash is washed repeatedly and the washings filtered, then the filtrate is evaporated to dryness, weighed and calculated to percentage; this should not fall below 3 per cent. In exhausted leaves the soluble ash was found by Dr. J. Bell to be present on the average to the small extent of 0·7 per cent.

The alkalinity of the soluble ash may be estimated with advantage, the titration being performed with $\frac{N}{10}$ sulphuric acid, using methyl orange as an indicator; 1 cc of $\frac{N}{10}$ acid is equivalent to 0·0047 K_2O; the alkalinity of the soluble ash should not fall below 1 per cent. K_2O, that from exhausted leaves, according to Dr. Bell, shows on an average only 0·2 per cent. of alkalinity as K_2O.

Caffeine $C_8H_{10}N_4O_2$ is the alkaloid to which tea owes all its value, it was at one time described as theine, but the identity with the alkaloid of coffee has now been established. Tea is a valuable restorative after fatigue, whether mental or bodily; it is a powerful respiratory stimulant, but unlike cocoa it is not a food. Taken in moderation after a full meal it is not prejudicial to gastric digestion, that is provided it be not too strong and has not been too long infused; the practice of taking tea with meat meals, so much in vogue in Australasia, is not a good one, as tea under these circumstances is apt to retard digestion; a cup of tea *after* a heavy meal, according to Dr. Edward Smith, F.R.S., acts rather as an aid to digestion.

The abuse of tea, bringing with it grave nervous and dyspeptic symptoms, is no doubt an evil almost comparable with the abuse of alcohol, it is chiefly met with amongst the under-fed or badly-fed women dwelling in large communities such as colliery places or manufacturing centres.

COFFEE.

Coffee is prepared from the roasted seeds of *Coffea Arabica;* natural order, *Rubiaceæ.* When ground and properly infused it affords a stimulant of great value as a restorative; it removes the sensation of fatigue, and for those exposed to cold is a most suitable beverage, it does not increase the action of the skin to the same extent as hot tea and alcohol, but increases the heart's action, causing it to beat more quickly and more forcibly.

Roasting, which is conducted at a temperature of about 450° F., develops the aroma and flavour of the coffee, and at the same time renders the beans more friable, when roasted, they are ground and ready for use. After coffee has been ground it should be used at once, or else packed in air-tight tins to prevent loss of aroma.

Roasted coffee shows amongst other constituents:—

	Per cent.
Caffeine	0·82 to 1·05
Saccharine matter ...	0·41 to 0·43
Fat and Oil	13·5
Albumen	11 to 13
Ash	4·56 to 4·88
Moisture	0·63 to 1·13

The preparation of the coffee infusion is conducted much better on the continent than in England, the reason for this lies chiefly in the fact that less water and more coffee is used, and the flavouring is done with caramel instead of chicory; English people almost invariably use too little coffee; to make good coffee, from 1 ounce to 1½ ounces of coffee should be used with every pint of water.

The examination of coffee is conducted with a view to determine the nature and extent of foreign matter added.

Chicory is the substance chiefly added; chicory is the dried and roasted root of the wild endive (*Cichorium intibus*) which is added to give body and colour, if present in coffee it may be detected by dropping a pinch or two of the sample into some water in a glass, if chicory be present it will be seen to sink almost immediately, leaving the coffee floating for a while on the surface, the particles which sink are soft if they consist of chicory, and hard if composed of coffee, these may be identified with certainty by microscopic examination.

With the microscope, chicory shows dotted ducts, which appear as tubes with square ends, also a network of oval or rounded cells; coffee always shows some of the long spindle-shaped cells met with in the testa or outer covering of the bean, numerous spiral cells found in the raphe, oil globules, starch, and dark angular masses, all contained in cellular tissue, the cells of which are more irregular than those of chicory. The specific gravity of a 10 per cent. infusion is the usual test upon which a calculation as to the percentages of coffee and chicory present is made. A 10 per cent. decoction is made by placing 10 grammes of the sample in a tared flask and adding distilled water until there is 100 grammes of the mixture, this is boiled for fifteen minutes and the loss made good with water, the decoction is then filtered, cooled to 60° F., and the specific gravity taken; the specific gravity of a 10 per cent. coffee decoction is, as a rule, 1009·5, and never exceeds 1010·0 at 60° F., whereas a 10 per cent. decoction of chicory shows at the same temperature a specific gravity of 1021·7.

If with a 10 per cent. decoction of a sample we find, for example, a specific gravity 1015·6, it will be evident that chicory has been added. Taking 1009·5 as the specific gravity of a 10 per cent. decoction of coffee, and 1021·7 as that of a similar decoction of chicory, then $1021{\cdot}7 - 1009{\cdot}5 = 12{\cdot}2$, and 12·2 represents 100 per cent. chicory; but the sample showed a specific gravity 1015·6, so $1021{\cdot}7 - 1015{\cdot}6 = 6{\cdot}1$, so $12{\cdot}2 : 6{\cdot}1 :: 100 : x$, there is therefore 50 per cent. chicory in the sample.

CHAPTER XIII.

SPIRITS.

Rum continues to form part of the Naval ration for Seamen and Marines, though no longer issued to Officers. The quantity has been from time to time reduced so that now the non-abstainer only draws a little over 2½ oz. per diem, which is a little less than a glass, or an eighth of a pint of rum, 4·5 degrees under proof, *i.e.,* spirit containing about 46·9 per cent. by weight of absolute alcohol.

Rum is chiefly prepared in the West Indies and Guiana, and is made from the bye-products and refuse sugar juice of the cane sugar industry, the bye-products consisting of the skimmings of the sugar pans and uncrystalizable sugar known as molasses. The best rum is made from the skimmings, the medium quality from a mixture of skimmings and molasses, and the third quality from molasses. After the addition of water and some of the lees of the still to some of the above ingredients, the wash so prepared is placed in the fermenting vat where it remains a week or ten days, during which time fermentation progresses briskly, and after a time a scum rises to the surface and is removed about twice daily, with the result that at the end of the week or ten days the wort has become sufficiently attenuated and is fit for distillation, and run into the still. The old method of distilling yielded the best rum, in it the process required two distillations, in the first the distillate was known as "low wines," this on re-distillation yielded the strong rum known as "high wines."

Pure rum when first distilled is quite colourless, but storage in sherry casks or the addition of caramel, gives it the ordinary brown colour, the pleasant aroma of rum is due to the presence of butyric ether naturally present.* Well-matured rum is without doubt the most wholesome of spirits, whereas new rum is probably one of the least wholesome, as it is not only very intoxicating but its use is liable to lead to hepatic troubles in cold climates; no spirit improves with age so much as rum, it loses alcohol, gains œnanthic

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* A solution of butyric ether in 10 parts of spirits of wine, is sold under the name of essence of pine-apple or Ananas oil, and is much used for flavouring artificial rum and other spirituous liquors.

ether and becomes probably the least harmful of spirituous drinks. (In the year 1865 at Carlisle some rum known to be 140 years old was sold for the enormous sum of £3 3s. a bottle.) The Admiralty, mindful of these facts, only issue matured rum to ships, and this is always 4·5 degrees under proof.

		Per Cent. Alcohol.	
		By Weight.	By Volume.
British Proof Spirits contain		49	57
Commercial Cognac	15 u.p.	41	48
Gin	17 u.p.	40	47
Rum	15 o.p.	58	66
*Whiskey	15 o.p.	55	63

The examination of spirits chiefly aims at finding out the amount of alcohol contained and the detection of Fusel Oil (amyl alcohol) and methyl alcohol when present; these remarks therefore apply equally to all of the above mentioned spirits.

The following table shows the average composition of good spirits :—

	Sp. grav. 62° F.	Alcohol per cent. by weight	Alcohol per cent. by vol.	Solids per cent.	Ash per cent.
Brandy ...	0·920 to 0·934	49·15 to 42·65	56·95 to 50·15	1·2	0·05 to 0·2
Gin ...	0·930 to 0·944	44·55 to 37·65	52·15 to 44·75	1·2	0·1
Rum ...	0·874 to 0·926	69·20 to 46·40	76·15 to 54·10	1·0	0·1
** Whiskey	0·915 to 0·920	51·45 to 49·15	59·30 to 56·95	trace	0·2

The Sale of Foods and Drugs Amendment Act, 1879, lays down the minimum strength of Brandy, Whiskey and Rum, as

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* (The Chemistry of Common Life by Johnstone, New Edition, edited by Church. Published by Blackwood and Sons, 1894.

** Adapted from table in Parkes' Hygiene, edited by Notter, 1891.

25 degrees under proof, *i.e.*, a Sp. gr. of 0·9474 and 75 per cent. Proof Spirit, which is equivalent to about 35·8 per cent. by weight and 42·8 per cent. by volume of absolute alcohol. Gin is allowed to be still further diluted, *viz.*, 35 degrees under proof, *i.e.*, Sp. gr, of about 0·9563, 30·9 per cent. by weight, and 37·2 per cent. by volume of absolute alcohol. Proof Spirit at 60° F. has a Sp. gr. of 0·9198 and contains 49·25 per cent. by weight and 57·05 per cent. by volume of absolute alcohol, as shown in the Alcohol Tables, q.v.

It is often required to reduce a given quantity of spirits ascertained to be a certain number of degrees *over proof* to proof spirit, or a certain number *under proof*. The rule is this: Let x = the number of degrees the spirit is *over proof*. and y be the number of degrees the spirit is required to be made *under proof*: (if it is required to reduce the spirit to *proof* then $y = o$). Let n = the amount in volumes of spirit of the *ascertained strength* which will make 100 volumes of the *required strength*, and let m = the actual quantity of spirit it is required to dilute. Take the difference between Proof Spirit reckoned as 100 and y, multiply this difference by 100 and divide the result by 100 + x.

$$\frac{(100 - y) \times 100}{100 + x.} = \text{“}n\text{”}$$

If now we know that “n” Volumes will make, 100 how much will m make.

$$\frac{m \times 100}{n} = \text{number of gallons.}$$

of the required strength $\frac{m \times 100}{n} - m$ = the amount of water which must be added. Example: A sample of rum measuring 90 gallons is 15° o.p. and we require to reduce it to 4·5° u.p., how much water must be added.

$$\frac{(100 - 4{\cdot}5) \times 100}{115} = 83{\cdot}043$$

83·043 volumes of the sample rum will make 100 volumes of 4·5 u.p. rum,

and 90 gallons will make $\frac{90 \times 100}{83{\cdot}043} = 108{\cdot}377$ gallons.

and 108·377 — 90 = 18·377 gallons the amount of water which will have to be added. The Admiralty method of calculating is done in two distinct stages. First the spirit is reduced to proof strength and then from proof strength to the required strength *below proof*, it is as follows: Multiply the volume of rum in hand by the over proof strength, divide the result by 100, the result added to the amount in hand gives the number of proof gallons required, and the amount of water to be added is obvious. To take the previous example again:—

90 gallons 15 o.p.

$$90 \times 15 = 1350$$

$$1350 \div 100 = 13{\cdot}5 \text{ (= water to be added).}$$

$$90 \times 13{\cdot}5 = 103{\cdot}5$$

Having reduced the spirit to proof strength, it is required to further dilute it below proof (in this case to 4·5 u.p.). Then the quantity is multiplied by (in this particular case) 4·5 and divided (in this case) by 95·5, and the result thus obtained gives the amount of water required to be added to make it the required strength u.p.

$$\frac{103{\cdot}5 \times 4{\cdot}5}{95{\cdot}5} = 4{\cdot}8769 \text{ gallons.}$$

13·5 gallons of water had already been added to reduce the spirit to proof strength, so the total added = 18·3769 gallons; by the first method we obtained 18·377 gallons as the amount required.

The amount of alcohol present in a sample is found either by taking a given bulk of the sample at 60° F., then distilling until two-thirds of it have distilled over, then cooling the distillate and adding distilled water until the volume at 60° F. is equal to the original amount taken and then taking the specific gravity and referring to the alcohol tables when the amount of alcohol present is read off; or else we may determine the amount of alcohol as detailed in Chapter xi. on Lime Juice, by taking the specific gravity of the spirit at 60° F., then evaporating to one-third to drive off the alcohol and adding distilled water in sufficient quantity so that the whole measures at 60° F., the same as it did at first, when the specific gravity is again taken; the specific gravity *before* evaporation, subtracted from the specific gravity *after* evaporation, gives a number which must be deducted from unity (1·000), and the value thus obtained, on reference to the alcohol tables, gives the amount of alcohol originally present in the sample.

The total solids and ash are determined as in water analysis.

Fusel oil is an impurity chiefly met with in whiskey, and gin, but may be found in cheap brandy and spirits made from potato, beet-root or corn spirits ; it is a mixture of several homologous alcohols, the greater part of it can be isolated by fractional distillation, though after this, traces are still apt to remain, and are recovered with difficulty. Fusel Oil is chiefly composed of amyl-alcohol $C_5 H_{12} O$, which has a specific gravity of 0·817, and a boiling point of 132° C (the boiling point of ethyl alcohol being 78·4° C), and is recognisable by a peculiar penetrating smell.

Fusel oil from potatoes consists chiefly of iso-amyl alcohol, and often contains iso-butyl alcohol and decoic acids.

Fusel oil is much more poisonous than ethyl alcohol, and the maturing of whiskey and other spirits containing fusel oil causes the amyl-alcohol to split up into other bodies less irritating, this alteration in composition improves the flavour and causes the whiskey to become mellowed. If a spirit contains fusel oil in an appreciable quantity, it may be detected by pouring a little of it on the hand, rubbing the hands together and allowing the more volatile ethylic-alcohol to evaporate, then if fusel oil be present, a pungent suffocating smell is experienced when the hands are held over the mouth and nostrils. Another test is to take some of the suspected spirit (100 cc), distil at a temperature of about 78·4° C. to remove the ethyl-alcohol, then, to the residue in the flask when cool, add some ether and lastly some water, remove the ether layer and allow it to evaporate spontaneously, and to one portion of the residue add (1) two parts of acetate of potash and one part of strong sulphuric acid, when an odour of essence of jargonelle will be evolved, if fusel oil be present. To the other portion of the residue add (2) a little bichromate of potash and twice its bulk of strong sulphuric acid, when green oxide of chromium will be be formed if fusel oil be present. For the quantitative estimation of fusel oil and the methods for detecting methylic alcohol, the reader is referred to such works as Allen's *Commercial Organic Analysis*, or the work on Food and Drugs by Pearmain and Moor.

BEER AND STOUT.

Beer and *Stout* are issued to convalescent patients in Naval Hospitals, but these articles do not enter into the ordinary service dietary. In hospital, complaints are not unfrequently made as to the quality of the beer, which on investigation often prove groundless ; it is therefore a matter of importance for Naval Medical Officers to be able to form an opinion as to the fitness or otherwise of the beer or stout supplied.

Beer is a fermented malt liquor flavoured with hops or other vegetable bitter and containing amounts of alcohol varying from 1 to 10 parts by weight per cent. thus :—

Small Beer	contains	from	1 to 1·5	per cent.,	by weight	of Alcohol
Porter	,,	,,	3½ to 5½	,,	,,	,,
Brown Stout		,,	5½ to 6½	,,	,,	,,
Bitter and Strong Ales		,,	5½ to 10	,,	,,	,,

Ordinary Bitter Ale or Mild Burton show about 6 per cent. by volume of alcohol. Allsopp's Pale Ale about 6·4 per cent. by weight, or 8 per cent. volume. Guinness Stout XX about 5 per cent. by weight, or 6 per cent. by volume. Lager beers an average amount of about 4 per cent. by weight, or 5 per cent. by volume. Bavarian beers about 2 per cent. by weight, or 3 per cent by volume. English beer differs from German beer in being less aërated and containing rather more alcohol, in its preparation the fermentation is conducted at a higher temperature, and more rapidly, by means of *high* or surface fermentation ; the *low* or bottom fermentation, produced by a different variety of yeast being employed in the production of the Lager or German beers. The Burton beers owe their flavour largely, to the water of that place containing a considerable amount of calcium sulphate (18·96 grains per gallon) and total sulphates, including sulphates of potash, calcium and magnesium equal to 19·8 grains per gallon of SO_3.

Examination of Beer.

Beer should be clear and bright, that is to say show no turbidity, the smell should be agreeable, and the taste free from acidity and not persistently bitter. If turbid it will generally be sour, and if very acid show the Mycoderma aceti. The specific gravity, at 60° F. of English beer, is usually from 1·010 to 1·014. Porter and stout show a higher specific gravity, viz.: about 1·024, whereas the German Pilsener is usually 1·013.

The alcohol may be determined as described under Spirits or by Tabarie's method, in which the specific gravity is taken at 60° F. after which a definite quantity (100 or 150 cc) is boiled down to one third, and then made up to the original volume at 60° F with distilled water, when the specific gravity is once more taken. the amount of alcohol is then found by dividing the first specific gravity before boiling, by the second specific gravity obtained as detailed, and the quotient referred to the alcohol table on p. 202.

Acidity is divided into *fixed* and *volatile,* the fixed is due to non-volatile acids, chiefly lactic, but there may also be other acids such as succinic, tannic, or malic; the volatile are acetic and carbonic acids. The total acidity is determined by taking 20 cc of the beer, diluting with water and titrating with $\frac{N}{10}$ sodium hydrate, using litmus as an indicator, each 1 cc of $\frac{N}{10}$ sodium hydrate is equivalent to 0·005958 (in round numbers ·006) grammes of acetic acid ($HC_2 H_3 O_2$) acidity thus found is expressed in terms per cent. of acetic acid ($HC_2 H_3 O_2$).

Fixed acidity is found by taking 20 cc of beer, diluting to 100 cc and evaporating down to 50 cc, on titrating with $\frac{N}{10}$ sodium hydrate as before, we find the percentage amount of fixed acidity expressed as lactic acid 1 cc of the $\frac{N}{10}$ sodium hydrate being equal to 0·009 grammes of lactic acid ($HC_3 H_5 O_3$). The volatile acidity is found by taking the difference between the number of cc used when taking the *total* and *fixed* acidities, and multiplying the difference by 0·006, in order to express it in terms of acetic acid ($HC_2 H_3 O_2$) and calculating to percentage. The total acidity of good beer should not exceed 0·35 per cent., and will usually be about 0·2, and that of porter should not exceed 0·28 per cent., and as a rule will be found to be about 0·2 per cent., expressed as acetic acids.

Malt Extract: Beer evaporated to dryness yields "malt-extract," consisting of soluble substances from the hop, undecomposed sugar, gluten from the grain, and a small amount of glycerine and mineral matter; in estimating the extract, 5 cc is evaporated to dryness over a water bath in a platinum dish, and finally in a water oven until the weight is constant, the amount varies as a rule between 4½ and 8 per cent. In old Scotch ales it is more than in ordinary ale, and in stout it is usually about 6 or 7 per cent. The ash is obtained by incinerating the extract, and amounts as a rule to 0·3 or 0·4 per cent. It is unlikely that strychnine would be met with except in attempts at poisoning, the allegations at one time made on the Continent in regard to the use of strychnine in English Beer have long since been disproved; for the detection of this and such substances as picrotoxine, picric acid, &c., the reader is referred to such works as "Toxicology," by Woodman & Tidy; or "Foods, their Composition and Analysis," by Wynter Blyth; or the work on "Poisons, their Effects and Detection," by the same author.

Boric and salicylic acids are often employed with beer by brewers. Boric acid is detected as detailed in the chapter on Milk.

If present, salicylic acid can be readily detected by taking about 150 or 200 cc, evaporating down to ¼ over a water bath, and when cool extracting with ether, the salicylic acid is taken up by the ether, and on the evaporation of the ether, ferric chloride, ($Fe_2\,Cl_6$) gives the characteristic violet reaction.

WINES.

Wines are the result of the natural fermentation of grape-juice, that is to say they are fermented without the addition of yeast as is the case with malt liquors.

Wines are characterised by the presence of tartaric acid, and they also contain acetic acid, though to a less extent. In the production of wine, the grapes are gathered when ripe and placed in wooden troughs, where they are first pressed by the feet, and then by a screw-press ; when crushing grapes in the sherry wine-presses the men wear wooden clogs with nails on the soles and heels ; the reason for this primitive method is that the weight of the average man is just sufficient to express the juice without injury to the skins or branches of the grapes, which if pressed too much would yield bitter substances and ruin the wine, when the first juice is expressed, the crushed grape skins, are in Spain sprinkled with "yeso" a natural earth composed principally of calcium sulphate, the amount of "yeso" employed being a little over a kilogramme to a load of grapes weighing 812 kilogrammes, the addition of calcium-sulphate, which is deprecated by many, is said to cause the crushed skins to mass together, clear the wine, aid the maturing process and assist in the formation of the various volatile ethers, which produce the aroma or "bouquet" of a wine. According to many the addition of calcium sulphate gives rise to the formation of free sulphuric acid, but this is not so, what occurs is represented as shown in the *Lancet* for 29th October, 1898, by the following equation:—

$$2KH\,C_4\,H_4\,O_6 + Ca\,SO_4 = K_2\,SO_4 + Ca\,C_4\,H_4\,O_6 + H_2\,C_4\,H_4\,O_6$$

that is to say potassium acid tartrate is converted into insoluble tartrate of lime, which is precipitated, and free tartaric acid remains in the wine, it is on account of the presence of free tartaric acid that sherry was adopted in pharmacy as a solvent of iron and certain active principles of drugs. The potassium sulphate shown as a result of the addition of calcium sulphate, has been thought, by M. Lancereaux, to be the cause of the large amount of atrophic cirrhosis met with amongst wine-drinkers, but the evidence in support of this view is not forth-coming, and it is much more probable that it is the alcohol which is responsible for the pathological condition referred to. In regard to acidity a certain amount of acidity renders wine palatable, champagne is the least acid, next to it come marsala, port, and sherry; clarets and Rhine wines, as a rule, contain the most acid. The percentage composition of a few wines is as follows:—

Name of Wine	Alcohol by weight	Solids	Sugar	Fixed acid as Tartaric	Volatile as Acetic
Champagne	7·9	12·4	10·6	0·30	—
Port	18·5	4·2	1·6	0·25	·03
Sherry (amontillado)	13·98	1·82	0·197	0·35	·113
Sherry (oloroso)	16·22	8·865	3·85	·412	·126
Marsala	17·5	5·4	3·2	0·32	—
Madeira	16·7	5·0	2·1	0·54	—
Claret (St. Julien)	9·8	2·7	0·3	0·51	0·14

Wines, especially Port, Sherry, Madeira, are greatly improved by age, the "bouquet" improves chiefly as a result of etherification; the "vinosity" also greatly improves with age, the vinous odour of wine is due to an infinitesimally small amount of œnanthic ether, which appears to increase by being kept. A wine is described as *dry* when most of the sugar (glucose) has been converted into alcohol, and *fruity* when an appreciable amount of sugar still remains.

Examination of wine—*Specific gravity* is taken at 60° F preferably with a Westphal's balance. *Alcohol* may be estimated as described under beer. *Extract* is determined in a similar manner to that of beer, and the *ash* by ignition of the of the dried extract.

Acidity divided into fixed and volatile, is found by first finding the total acidity, by taking 20 cc of wine, diluting with water, and titrating with $\frac{N}{10}$ Na HO using phenolphthalein, as an indicator and noting the number of cc $\frac{N}{10}$ Na HO used. Fixed acidity is found by diluting 20 cc of the wine with 80 cc of distilled water and boiling down to a third, then making up to the original volume with distilled water and titrating with $\frac{N}{10}$ Na HO and phenolphthalein, the number of cc $\frac{N}{10}$ Na HO used multiplied by 0·0075 gives the amount of fixed acidity as tartaric acid $(H_2 C_4 H_4 O_6)$ in 20 cc this is then calculated to per centage. The difference in the number of cc $\frac{N}{10}$ Na HO used in determining the *total* and *fixed* acidities, multiplied by 0·006 gives the volatile acidity in 20 cc expressed as acetic $HC_2H_3O_2$ this is then calculated to percentage. The artificial colouring matters most often employed, are logwood, cochineal, fuchsine, and magenta. The method employed by Dr. Dupre for the detection of artificial colouring is a useful one, it is conducted as follows—

A 10 per cent. solution of good, clear gelatine is made, and allowed to set in a mould, after which it is cut up into little cubes ¾-in. square. Several of these are soaked in the wine for 24 hours, after which they are removed, washed in cold distilled water and cut into; in natural wine the colour does not penetrate for more than 1/16 inch, whereas the stains mentioned above will penetrate nearly if not quite to the centre. Another test, described by Pearmain and Moor, is to add ammonium hydrate to some of the suspected wine until it is alkaline in reaction, after which a little ammonium sulphide is added, and the liquid filtered. If the wine be genuine the filtrate will be of a greenish colour, if artificially coloured it will be some other colour, such as red, violet, brown, &c.

In the Paris Laboratory several preliminary tests are employed to detect artificial colouring. In one of these tests, sticks of chalk steeped in a 10 per cent. solution of egg-albumen are dried first in the air and then at 100°C; excess of albumen is removed from the chalk by scraping, after which two or three drops of wine are allowed to fall on the chalk, natural wine gives a gray colour, or perhaps a bluish tint if the wine be young, but green, violet, or rose, if artificial.

Another French test is to add baryta-water to the wine until it is of a greenish hue, and then shake it up with acetic ether or amylic alcohol, pure wine shows no colour in the upper layer, either with or without the addition of acetic acid. If basic coal-tar colours are present, the solvent is coloured according to the nature of the dye, examples of which are fuchsine, mauvene, amidobenzene, &c.*

Preservatives, such as Boric and Salicylic Acids are often added to wine and may be detected as described in previous chapters.

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* Foods—Composition and Analysis, P. 500, 3rd Edition, A. W Blyth.

ALCOHOL TABLES.

Specific gravity at 60 deg. F.	Absolute Alcohol by weight per cent.	Absolute Alcohol by volume per cent.	Proof Spirit per cent.	Specific gravity at 60 deg. F.	Absolute Alcohol by weight per cent.	Absolute Alcohol by volume per cent.	Proof Spirit per cent.	Specific gravity at 60 deg. F.	Absolute Alcohol by weight per cent.	Absolute Alcohol by volume per cent.	Proof Spirit per cent.	Specific gravity at 60 deg. F.	Absolute Alcohol by weight per cent.	Absolute Alcohol by volume per cent.	Proof Spirit per cent.
1·000	0·00	0·00	0·0	·964	25·70	31·20	54·7	·928	45·50	53·15	93·2	·895	60·30	68·00	119·2
·999	0·55	0·65	0·1	·963	26·45	32·05	56·2	·927	45·95	53·65	94·1	·894	60·70	68·35	119·8
·998	1·05	1·30	2·4	·962	27·15	32·90	57·6	.926	46·40	54·10	94·8	·893	61·10	68·75	120·5
·997	1·60	2·00	3·5	·961	27·80	33·60	59·0	·925	46·90	54·60	95·6	·892	61·55	69·15	121·1
·996	2·15	2·70	4·9	·960	28·45	34·40	60·3	·924	47·30	55·10	96·5	·891	62·00	69·96	121·9
995	2·75	3·50	6·1	·959	29·10	35·10	61·6	·923	47·80	55·55	97·4	·890	62·45	69·95	122·6
·994	3·30	4·15	7·2	·958	29·70	35·80	62·8	·922	48·25	56·05	98·2	·889	62·85	70·35	123·3
.993	3·90	4·90	8·6	·957	30·35	36·55	64·1	·921	48·65	56·50	99·0	·888	63·25	70·75	124·0
.992	4·50	5·65	9·9	·956	31·00	37·35	65·4	·920	49·15	56·95	99·8	·887	63·70	71·20	124·7
·991	5·15	6·40	11·2	·955	31·55	37·95	66·5					·886	64·15	71·60	125·4
·990	5·75	7·15	12·6	·954	32·15	38·60	67·6	·9198	49·25	57·05	100·OP.S.	·885	64·55	71·90	126·0
·989	6·40	8·00	14·1	.953	32·70	39·20	68·7					·884	65·00	72·35	126·3
·988	7·10	8·80	15·5	·952	33·30	39·90	70·0	·919	49·65	57·40	100·6	·883	65·40	72·75	127·5
·987	7·80	9·65	16·9	·951	33·80	40·55	71·0	·918	50·10	57·90	101·5	·882	65·80	73·15	128·2
·986	8·50	10·55	18·4	·950	34·40	41·20	72·2	·917	50·55	58·40	102·3	·881	66·25	73·50	128·9
·985	9·20	11·40	20·0	·949	35·00	41·85	73·3	·916	51·00	58·85	103·1	·880	66·65	73·90	129·6
·984	9·90	12·35	21·5	·948	35·50	42·40	74·3	·915	51·45	59·30	103·9	·879	67·05	74·30	130·2
.983	10·65	13·20	23·1	·947	36·05	43·00	75·4	·914	51·90	59·75	104·7	·878	67·55	74·70	130·9
·982	11·45	14·10	24·7	·946	36·55	43·60	76·4	·913	52·35	60·15	105·5	·877	67·95	75·10	131·6
·981	12·25	15·10	26·5	.945	37·10	44·15	77·4	·912	52·80	60·65	106·5	·876	68·40	75·45	132·2
·980	13·00	16·00	28·0	·944	37·65	44·75	78·4	·911	53·25	61·05	107·0	·875	68·80	75·80	132·9
·979	13·80	17·00	29·8	·943	38·20	45·40	79·5	·910	53·65	61·50	107·8	·874	69·20	76·15	133·5
·978	14·65	18·00	31·6	·942	38·65	45·85	80·4	·909	54·10	61·95	108·5	·873	69·65	76·60	134·3
·977	15·45	19·00	33·3	·941	39·15	46·40	81·4	·908	54·55	62·40	109·3	·872	70·05	76·95	134·9
·976	16·30	20·00	35·1	·940	39·70	47·00	82·4	·907	54·95	62·80	110·0	·871	70·50	77·35	135·6
·975	17·10	21·00	36·8	·939	40·15	47·50	83·3	·906	55·45	63·30	110·9	·870	70·85	77·65	136·1
·974	17·90	21·95	38·5	·938	40·65	48·05	84·1	·905	55·90	63·70	111·6	·869	71·30	78·10	136·6
·973	18·80	23·05	40·5	·937	41·15	48·60	85·1	·904	56·35	64·10	112·3	·868	71·75	78·45	137·4
·972	19·55	23·90	42·0	·936	41·65	49·10	86·1	·903	56·75	64·55	113·1	·867	72·20	78·75	138·1
·971	20·35	24·90	43·6	·935	42·15	49·65	87·0	·902	57·20	65·00	113·9	·866	72·55	79·15	138·8
·970	21·10	25·75	45·2	·934	42·65	50·15	87·9	·901	57·60	65·35	114·6	·865	73·00	79·55	139·4
·969	21·95	26·85	46·9	·933	43·15	50·70	88·9	·900	58·05	65·80	115·4	·864	73·45	79·95	140·1
·968	22·75	27·75	48·6	·932	43·60	51·20	89·8	·899	58·55	66·30	116·2	·863	73·80	80·25	140·7
·967	23·50	28·65	50·2	·931	44·10	51·70	90·6	·898	58·95	66·65	116·8	·862	73·25	80·60	141·3
·966	24·25	29·55	51·8	·930	44·55	52·15	91·4	·897	59·35	67·05	117·5	·861	74·70	81·00	141·9
·965	25·00	30·40	53·3	·929	45·00	52·70	92·3	·896	59·85	67·55	118·4	·860	75·10	81·35	142·6

APPENDIX.

METRICAL WEIGHTS AND MEASURES.

(*a*) LENGTH.

Millimetre = 0·03937 English inches
Centimetre = 0·39371 ,,
Decimetre = 3·93708 ,,
Metre = **39·37079** ,,
Decametre = 393·70790 ,,
Hectometre = 109·3633 English yards
Kilometre = 1093·6330 ,,
Myriametre = 10936·3305 ,,

(*b*) AREA.

Centiare or square metre = 10·764 square feet
Are or 100 square metres = 1076·429 ,,
Hectare or 10,000 square metres = 107642·993 ,,
100 Hectares = 1 square kilometre = 247 acres

(*c*) CAPACITY.

1 Millilitre or cubic centimetre = 0·061 cubic inch.
1 Litre or cubic decimetre = 1000 cubic centimetres = 1·76077 pint.

(*d*) WEIGHT.

1 Milligramme = 0·01543 English grains
1 Centigramme = 0·15432 ,,
1 Decigramme = 1·54323 ,,
1 Gramme = **15·43235** ,,
1 Kilogramme = 1000 grammes = 2·2 lb. *avoirdupois*

—o—

To convert	millimetres	to inches	multiply by	0·03937
,,	centimetres	,,	,,	0·39371
,,	decimetres	,,	,,	3·93708
,,	metres	,,	,,	39·37079
,,	inches	to millimetres	,,	25·4
,,	,,	to centimetres	,,	2·54
,,	,,	to decimetres	,,	0·254
,,	,,	to metres	,,	0·0254

Milligrammes per 100 cc = parts per 100,000
Centigrammes per 1000 cc = parts per 100,000

To reduce	grammes to grains	multiply by	15·432
,,	grains to grammes	,,	0·0648
,,	ounces to grammes	,,	28·349
,,	kilogrammes to pounds	,,	2·2046
,,	pints to litres	,,	0·5676
,,	pints to cubic centimetres	,,	567·936
,,	gallons to litres	,,	4·541
,,	litres to gallons	,,	0·22

—o—

Relations of Measures and Weights.

1 cubic inch of distilled water at 62° F. and 30 inch barom. = 252·458 grains.

1 fluid ounce is the measure of 1 ounce or 437·5 grains of water.

1 pint is the measure of 1·25 lb. or 8750·0 grains of water.

1 gallon is the measure of 10 lbs. or 70,000 grains of water.

—o—

Co-efficients required in Volumetric Analysis.

DECI-NORMAL ACID SOLUTION.

Oxalic Acid	0·0063
Sulphuric Acid	0·0049
Baryta $(Ba(HO)_2$	0·00855
Caustic Potash (KHO)	0·0056
Caustic Soda (NaHO)	0·004

DECI-NORMAL SODA SOLUTION.

Caustic Soda	(NaHO)	0·004
Acetic Acid	$(H\ C_2\ H_3\ O_2)$	0·006
Tartaric Acid	$(H_2\ C_4\ H_4\ O_6)$	0·0075
Lactic Acid	$(H\ C_3\ H_5\ O_3)$	0·009
Oxalic Acid	$(H_2\ C_2\ O_4\ 2\ H_2\ O)$	0·0063
Hydrochloric Acid	(HCl)	0·00365
Sulphuric Acid	(H_2SO_4)	0·0049

DECI-NORMAL SOLUTION OF NITRATE OF SILVER.

Argentic Nitrate	0·016869
Chlorine (Cl)	0·003519
Sodium Chloride	0·005807

DECI-NORMAL IODINE SOLUTION.

Iodine	0·01259

PAVY'S SOLUTION.

100 cc = 0·05 gramme glucose.
100 cc = 0·0962 gramme lactose.

FEHLING'S STANDARD SOLUTION OF COPPER.

(Two Solutions).

No. 1 consists of 34·64 grammes of cupric sulphate dissolved in water with the aid of 0·5 cc of strong sulphuric acid, and diluted to 500 cc.

No. 2 is made by dissolving sodium hydrate 77 grammes; tartarated soda 176 grammes; distilled water sufficient to make the whole measure 500 cc.

When required for use No. 1 and No. 2 are used in equal parts, and 10 cc of the mixture are equivalent to:—

Glucose	0·050 gramme
Maltose	0·0807 ,,
Lactose	0·0678 ,,
Inverted Cane Sugar	0·0475 ,,
Inverted Starch	0·045 ,,

—o—

LIST OF THE ATOMIC WEIGHTS OF THE CHIEF ELEMENTS IN COMMON USE IN ANALYTICAL WORK.

	True Atomic Weight	*Approximate Atomic Weight*
Aluminium	26·90	27·0
Antimony	119·00	119·0
Arsenic	74·50	75·0
Barium	136·40	137·0
Bismuth	207·30	207·5
Boron	10·85	11·0
Bromine	79·35	79·0
Calcium	39·71	40·0
Carbon	11·91	12·0
Chlorine	35·19	35·5
Chromium	51·74	52·0
Copper	63·12	63·0
Gold	195·70	196·0
Hydrogen	1·00	1·0
Iodine	125·90	127·0
Iron	55·60	56·0
Lead	205·35	205·5
Magnesium	24·18	24·0
Mercury	198·80	199·0
Nitrogen	13·94	14·0
Oxygen	15·88	16·0
Phosphorus	30·80	31
Potassium	38·83	39·0
Silver	107·11	107·0
Sodium	22·88	23·0
Sulphur	31·82	32·0
Zinc	64·91	65·0

INDEX TO PART II.

PART III.

METEOROLOGY.

PART III.

CHAPTER I.

BAROMETRIC PRESSURE.

That the air has weight is a matter of common observation, for we know that bodies whose supporting walls are slender can remain apart if full of air, but collapse when empty; again we know that an air-tight box can be exhausted of air, and that when so exhausted weighs less than when full, the difference in weight denoting the weight of the air contained.

At 29·92 inches and 32° F. a cubic foot of air weighs 573·5 grains, at 30·00 inches and 60° F., 534·47 grains. The weight of the atmosphere at sea-level exerts a pressure of 14·64 lbs. on the square inch when the mercurial barometer stands at 29·92 inches or 14·73 lbs. at 30 inches. Bulk for bulk air is 760 times lighter than water.

Air is considered by Lord Kelvin to consist of a large number of molecular particles, so minute that 500 millions of them placed in contact would only occupy a line 1 inch in length. The rate at which these particles vibrate depends on their temperature, and the amplitude of these vibrations is also dependent on temperature, so that gases are said to expand in a regular manner, viz., $\frac{1}{273}$ of their volume for each 1° C. Consequently a volume of gas which occupies 1 cubic inch at 0° C. would occupy 273 cubic inches at 273° C., or theoretically nothing at – 273° C., but we know that long before that temperature could be reached the vibration of the particles would be insufficient to prevent cohesion and show, firstly, the property of liquids, and lastly, the substances would become rigid, *i.e.*, solid. Charles' law enunciates, that provided the pressure be constant, the volume is proportional to its absolute temperature. Boyle's law states, that with a constant temperature the volume varies inversely with the pressure.

Barometers are instruments devised for measuring the weight of the atmosphere; this is done either by indicating by the height of a column of fluid which the air is capable of supporting, or by indicating the pressure by means of springs and an exhausted metallic box as with an aneroid barometer. The height of the column shown in fluid barometers is inversely proportional to the density of the fluid. Mercury is the commonest fluid employed, and in its simplest form a mercurial barometer consists of a tube about 34 inches in length, closed at one extremity, filled with mercury, and then immersed in a vessel containing mercury, taking care to prevent the introduction of air; under ordinary circumstances the mercury will fall to a height of about 30 inches, and the space above the mercury in the tube will only contain a little mercury vapour, this is in fact almost a perfect vacuum, and is known as the Torricellian vacuum. The ordinary range of barometric pressure at the sea-level is between 28 inches and 30·5 inches, but a height of 31·27 inches has been registered, and one so low as 27·124 inches, the scales of barometers are therefore marked off between 27 inches and 32 inches. The scale being liable to alteration in length with variations of temperature, all the best barometers have the scale marked off on brass, because the co-efficient of expansion of brass is well-known. If wood were employed this would be uncertain, as different woods expand to different extents. It will readily occur to anyone that if we lay off the scale of a barometer at any particular time, the scale will be correct for that time, and on any subsequent occasion when the pressure may be the same, but not for any other pressure, because the level of the mercury in the cistern must vary when the mercury rises or falls in the tube. Various methods have been devised for obviating this source of error. It can be met by:—

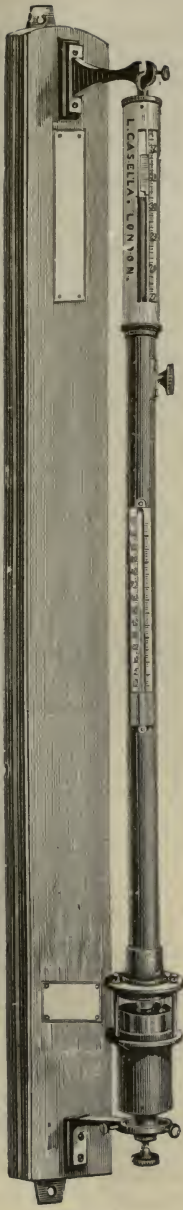
(1). A barometer with a *pliable base* to its cistern, as in Fortin's barometer, so arranged that the level in the cistern may be always brought to the same point before taking a reading.

(2). By employing a *contracted scale*, as in the Kew marine barometer, in which the inches are not true inches, but shortened to an extent, varying with the ratio of the sectional area of the cistern to the sectional area of the tube.

(3). By employing a *Syphon* barometer, in which the true reading is the difference between the heights of the fluid in the two arms of a U tube with arms of different length, one arm (the longer) is closed at the top, whereas the shorter one is open.

(4). By a *capacity* correction.

Fortin's barometer has the lower end of its cistern made of boxwood and the upper part of glass, so that the level of

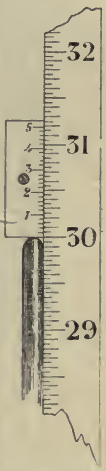


FORTIN'S BAROMETER

Fig. 55

the mercury in the cistern may be seen; the bottom is closed by buckskin, and the top by a brass lid from which depends an ivory pointer, the tip of which is called the *fiducial* point; at the bottom of the case enclosing the cistern is an orifice through which passes a screw which presses on a wooden button against the buckskin. To set the instrument the screw is turned so that the level of the mercury is raised until it reaches the fiducial point. A reading is taken, and then the screw turned down so that the mercury is no longer in contact with the pointer. The scale is marked in true inches, sub-divided into 0·1 and 0·05 of an inch. This barometer, like other fluid barometers, cannot be accurately read nearer than 0·05 of an inch without the aid of a vernier. The vernier is a sliding scale divided into divisions, so that n division of vernier $= n +$ or $-$ 1 division of the fixed scale. The ordinary vernier has 25 divvisions, which are equal to 24 of the fixed scale, each of which is ·05 inches apart, one division of the vernier is therefore smaller than one division of the fixed scale by $\frac{1}{25}$ of ·05 inches, or expressed in decimals, 0·04 × ·05 = 0·002 inches. To read the barometer with a vernier, the bottom of the vernier must be brought down so that its lower end forms a tangent to the meniscus of the column of mercury in the tube, and the eye must be exactly in the same straight line with the bottom of the vernier, then notice where one division of the vernier corresponds with one division of the fixed scale, this can of course only be at one point, except in the case where top and bottom both correspond to a line on the scale, and then the reading is obvious. We therefore count up the number of divisions from the bottom of the

Fig. 56



VERNIER.
(*Reading of Barometer in this case is 29·946 in.*)

vernier, where a line of the vernier corresponds with one of the fixed scale and add this amount on to the reading of the fixed scale; thus, supposing the scale reading showed 29·15 inches, and the sixth line of the vernier coincides with a line on the scale, then our reading will be 29·15 + (6 × ·002) = 29·162.

The special features of the Kew marine barometer are:—

Gay Lussac's Air Trap (in Kew Marine Barometer).

Fig. 57

(1). That the bore of the tube for the greater part of its extent is narrowed, so as to avoid the pumping and sucking action of the mercury which occurs in a wide tube as a result of the motion from side to side, which must, to a certain extent, occur on board ship despite the precautions taken in the way the barometer is slung.

(2). In order to prevent the ingress of air or moisture, a pipette, known as Gay Lussac's pipette, (A.B. *Fig.* 57) is inserted in the course of the tube, this is introduced in such a way that air or moisture gaining access to the tube lodges at the point marked A in the *figure*, and so is prevented from reaching the torricellian vacuum.

(3). The cistern is made of iron, because iron is not acted upon by mercury, and it has a small opening at its upper part guarded by a leather diaphragm which allows the air pressure to act but prevents any escape of the mercury.

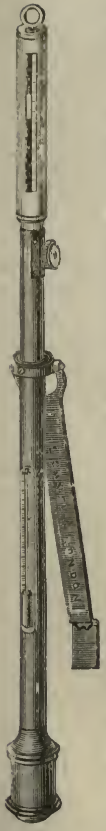
(4). But *the* special feature of the Kew marine barometer is the contracted scale, in this the inches are not true inches, but each is 0.04 less than a true inch, the 0·04 being the ratio of the sectional area of the cistern to the sectional area of the tube which are in the Kew marine barometer 1·25 inches and 0·25 inch in diameter respectively. The number of inches indicated at the top of the fixed scale is the number of inches marked off from a given point on the cistern, and each of the inches on the scale below this are true inches less 0·04 inch.

Kew Marine barometers are fitted with an arm made of hammered brass, which fits into a socket attached to a bulkhead, and as an additional security against jolting the arm is provided with a hinge at its upper side where it fits into the socket, and the barometer is slung in gimbals, so that in whatever direction the ship may move, whether rolling or pitching, the barometer hangs vertically, the arm being sufficiently long to prevent the instrument from touching the bulkhead against which the arm is fastened. The vernier in the Kew Marine is similar to that in Fortin's barometer.

All good barometers have a thermometer attached, so that the temperature of the instrument and the temperature of the mercury contained shall be known at the time of observation.

The Syphon barometer, as we have already said, consists of a U tube, the long arm of which is closed and the short arm open. The tube is filled with mercury so that there is no air above the mercury in the closed arm; when placed in position, the mercury in the closed arm will, as in the ordinary straight tube instrument, fall to a certain level, depending upon the weight of the atmosphere at the time, and above it will be a torricellian vacuum; a rise in the long tube causes a fall in the short tube, and vice-versa. The difference in the two readings gives the actual height of the barometer, thus, suppose the long arm shows 36·5 inches and the short 6·4 inches, the reading = 30·1 inches.

Capacity correction depends on the ratio of the area of the tube to the area of the cistern, the larger relatively the cistern is to the tube, the less will be this error or correction. The necessity for a capacity correction is understood if we suppose the scale to be laid off from a certain point which is called the neutral point; now if the barometer rises in the tube it must fall in the cistern, and the difference between the new level and the neutral point will have to be added; conversely, if it falls in the tube it must rise in the cistern, and the difference must be subtracted. Capacity correction remedies this.



Kew Marine Barometer.

Fig. 58.

Other errors are: *Index* error, which may be additive or subtractive, and is determined separately for each instrument, and *Capilliarity,* this varies with the tubes employed, and is less with boiled tubes than other tubes; the capilliarity correction is always additive. There are also certain corrections required for all instruments, viz.: those for temperature and altitude.

Aneroid Barometers are instruments for measuring atmospheric pressure without the aid of a fluid, hence the name aneroid—*ἀ* (privative) and *νηρός* (water). These instruments are, as a rule, very sensitive, and generally very accurate, but owing to the deterioration of the mechanism from rust, or possibly from injury through rough usage, they may become incorrect. They are very convenient for travellers, and instruments are made which are so graduated, that the height above sea level, or the height to which the traveller has attained, may be determined by observing the atmospheric pressure indicated as an ascent is made. The construction of an aneroid barometer is as follows: two corrugated German silver discs are soldered together so as to form an air-tight box, which is then exhausted, or nearly exhausted of air, and fixed to a metal plate by means of a pin; if atmospheric pressure increases, the top and bottom of the box are approximated, if pressure diminishes, they tend to separate. By means of a spring which resists compression, and so supports the top of the vacuum chamber, pressure is measured and the movements which occur are communicated to a lever compensated for changes of temperature by being composed of iron and brass; this lever is in turn connected to a chain wound round a spindle which carries an index. As the box expands with diminished pressure, the chain moves the pointer to the left, and when the chamber is compressed it moves the lever to the right. The chain would tend to become slack when pressure diminished were it not for a watch spring which keeps it always wound round the spindle. The ordinary barographs in use are aneroids, the pointer of which carries a pen which gives a tracing on a chart carried by a clockwork revolving drum, and so we are able to have continuous readings of the barometer for a week at a time, after which the clock is again wound up and a new chart placed in position.

At important meteorological stations, such as Kew Observatory, a photograph is taken continuously by means of a pencil of light falling on sensitised paper through the Torricellian vacuum of an ordinary mercurial barometer.

Ordinary altitudes may be calculated according to the method devised by Mr. R. Strachan, which is as follows:—Take the difference in barometric pressure between two places in one-hundredths of an inch and multiply this difference by nine, and the result will give the difference in height between the two stations in feet. For moderate heights and ordinary temperatures, starting at sea level, the barometer falls one inch for a rise of about 900 feet; *e.g.,* If the barometer at sea level shows 31 inches of pressure, at 857 feet elevation it will record a pressure of 30 inches; at 886 feet 29 inches; after 918 feet more 28 inches; and after an additional 951 feet it will stand at 27 inches. As we ascend, the air becomes rarer through a considerable portion of the atmosphere being below it, we have to ascend greater and greater distances for a corresponding fall of pressure. It will be seen that for a fall of four inches we have to ascend 3,612 feet, which gives a fall of one inch for every 903 feet as an average fall for readings at these heights; but when we get up higher, the fall in the barometer for each succeeding 900 feet is well under the inch, so that the factor nine previously mentioned, must be increased. The following table shows the factor to be employed, and the method of using the table, *fig.* 59, is as follows:—

Suppose you have two stations A and B, and it is required to ascertain the difference in height between them; take the mean of the two barometric readings at A and B, and also the mean temperature at these two stations and see on the charts where one of the slanting lines cuts both of these values, and note the value of the slanting line as indicated; this value is the factor which must be used to multiply the difference in the readings between the two stations in order to get the difference in height between them.

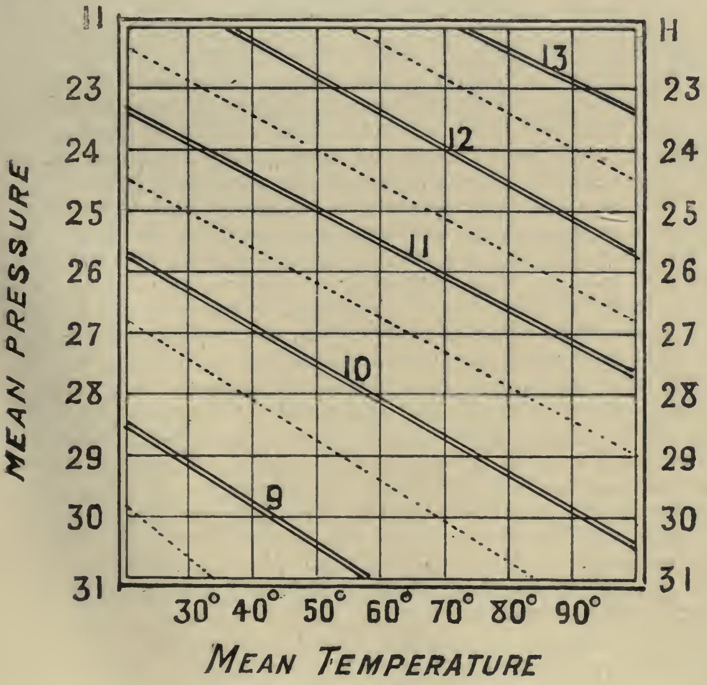


Fig. 59.

For example :—The barometric pressure at A is 30 inches, and at B it is 28 inches, the mean of these is 29 inches, and the temperature at A is 60° and at B is 40°, the mean of which is 50°; on referring to the chart the slanting line which cuts 29 inches and 50° is nine, so now taking the difference between A and B in $\frac{1}{100}$ of an inch, we get $\begin{array}{r}3000\\2900\\\hline 100\end{array} = 100$, and this multiplied by nine, gives a result 900, which is the difference in height between A and B taken in feet. Supposing A has given a reading of 26 inches and B of 24 inches, and the mean temperature had been 40°, we should have had 10·5 as the factor as represented by the slanting line, and the height of B above A would have been $200 \times 10{\cdot}5 = 2100$ feet.

In distributing water, it frequently happens that the water has to be conveyed from a higher to a lower level by means of a syphon. In cases where it has first to be carried *over* some object *above* the level of the fluid at the higher level, the height to which the fluid can be taken in this manner is dependent on the atmospheric pressure, so that in constructing syphons, the lowest pressure which may be experienced at any time has to be taken into consideration.

Effects of decreased or increased atmospheric pressure:—

Diminished Pressure.—The effects of diminished pressure begin to be noticeable when a height of between 2,800 and 3,000 feet has been attained, these consist in quickened respiration and pulse, increased evaporation from the skin and lungs (due to the dryness of the air), and diminished secretion or urine, the appetite is improved and there is a buoyancy of spirits with an increased capability for exercise. When the diminution in pressure equals between five and six inches of mercury, then congestion of mucous membranes occurs followed, if the air be very rarefied, by hæmorrhages from these parts, there will also be dyspnœa, headache, and a feeling of weightiness about the limbs. Mountain air, where there is considerable diminution in atmospheric pressure will aggravate the following conditions: pulmonary emphysema, chronic bronchitis, and bronchiectasis, cardiac affections and diseases of the great vessels, tuberculous laryngitis. Diseases of the brain and spinal cord and neurotic conditions where there is a tendency to hyper-sensibility; on the other hand many disorders and diseases may be cured or considerably benefited by mountain air with its rarefied atmosphere, such as chronic pleurisy, and cases where there is deficient expansion of the chest, early and chronic tuberculosis and hæmoptysis due to tubercle where the disease is not too far advanced. Cases of anæmia improve wonderfully under mountain air because as in the case of tuberculous disease the dryness and stillness of mountain air with the accompanying increase of diathermancy over that of the air at low levels permit the full effects of sunshine and an open air life without the enervating effects of a high temperature.

Increased Pressure.—The circumstances under which atmospheric pressure sufficiently increased to give rise to symptoms are experienced, are during diving operations and work in caissons (pneumatic chambers), for the construction of piers and foundations of bridges at great depths where work is sometimes conducted under a pressure equal to that of two or three atmospheres; the pressure of the air in deep mines is naturally greater than that at the surface, but the difference is so slight that it may be disregarded. Where the pressure amounts to that of two or three atmospheres, the following symptoms may be noticed—prickings, headache, deafness, preceded by singing in the ears, epistaxis may also occur; the danger, however, is not so much in the increase of atmospheric pressure as in the too sudden removal of pressure, if divers are allowed to come to the surface too suddenly, hæmorrhages into the spinal cord or elsewhere are liable to occur, followed by paralysis or death, and the same thing occurs in pneumatic chambers when workmen emerge from them without the precaution being taken of reducing the pressure gradually by means of air locks.

CHAPTER II.

HEAT.

The term climate is used to convey an impression as to the meteorological conditions existing in a country or place dependent upon *temperature* and *relative humidity*.

Temperature is the quality of a body in virtue of which it feels hot or cold, and this feeling of heat or cold is materially affected by the conductive power of the body.

When heat passes from one body to another the one which loses heat is said to be the one of a higher temperature.

Heat can be expressed quantitatively, and the unit of heat is the amount of heat required to raise 1-lb. of water from 0° to 1°C.

The specific heat of a substance is the ratio of the amount of heat required to raise a given mass of the substance 1°C to the amount of heat required to raise an equal mass of water from 0° to 1°C.

The relation between heat and temperature has been compared to the difference between the quantity and the level of fluid in two vessels ; the level in two vessels of dissimilar size may be the same, and yet the quantities of fluid widely different, likewise the *temperature* of two substances may be the same, and yet the *amount* of heat contained in the two masses widely different.

Heat is the effect of radiant energy on matter, more especially of the comparatively long and slowly vibrating waves.

The difference between a body in the solid, liquid, and gaseous states depends upon the rate of motion of its particles. In solids the particles vibrate slowly and cohesion confines these vibrations to very minute paths. In fluids the particles show much more internal movement, and this movement has in part overcome cohesion and the body shows fluidity. In gases the vibrations are so large that cohesion has been overcome, the particles do not interfere with one another until they come very close together and then repulsion takes place between them. This molecular theory explains the phenomenon of evaporation, with which we shall deal later on.

Heat is the total *amount* of molecular vibration. Temperature depends on the *rate* of that vibration.

The length of heat waves, like other waves, refers to the distance between the crests (C) or troughs (T) of the waves, amplitude to the depth from crest to trough vertically. In the *figure* the double-headed arrows A and L indicate amplitude and length. When the temperature of a body is raised, the length and amplitude of the vibrations of its particles increase, the result is that the body expands or becomes less dense. The co-efficient of linear expansion of a substance is the ratio of the increase in length of a bar of the substance, the result of an increase in its temperature of 1°C, to the original length of the bar at 0°C.

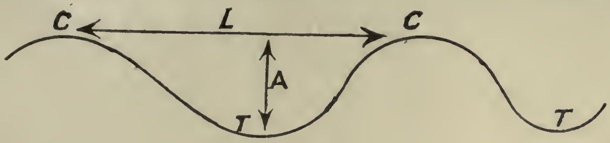


Fig. 60.

Expansion of bodies by heat is taken advantage of in the construction of thermometers. Fluids are for ordinary purposes the most convenient, and of these alcohol and mercury are the only ones which we need consider here ; alcohol being employed for low and mercury for high temperature.

Advantages of Mercury.

Mercury can readily be obtained pure. It has a low specific heat, and is a good conductor, readily acquiring the temperature of the body in contact without chilling it to an appreciable extent.

It is liquid through a wide range of temperature, viz.: from −40°F to + 662°F. It does not wet the envelope in which it is contained.

Alcohol has the advantage of remaining liquid at a temperature at which mercury is solid. Thilorier exposed alcohol to a temperature of −148°F without freezing it. It has the disadvantages of being less sensitive and of volatilising at even moderately high temperatures.

In making a thermometer it is important that the tube should have been calibrated, and any tube with inequalities of bore rejected.

The bore should be very slight compared with the external diameter of the tube.

The bulb should be thin, and exposing a wide area. Before a thermometer is graduated it ought to be laid aside for some considerable time, in order to allow the glass to contract to its permanent size. This period may be considerably reduced if the thermometer has been annealed by Denton's process with hot oil. Thermometers should be graduated by first plunging the bulb and a portion of the stem into melting ice and leaving it there for some little time, then the exact position of the column is noted. It is important to note that the melting point of ice and not the freezing point of water is taken as the starting point, because many circumstances affect the freezing point of water, whereas the melting point of ice is constant. The boiling point is determined by immersing the instrument in steam, generated by an instrument called a hypsometer, and it is important in making this point to note the height of the barometer, as the barometer affects this temperature considerably, and the boiling point should mean the temperature at which pure distilled water boils, when the barometer stands at 760 millimeters or 29·9215″ of mercury at 0°C at the sea level in latitude 45°, every alteration of pressure affects the boiling point in the proportion of 1·4°F for every difference of 1″ mercury in barometric pressure.

The boiling point at elevated stations is so low that it is insufficient to conduct the ordinary purposes of cooking, the temperature, therefore, has to be increased either by boiling the water in some apparatus like Papin's digester, or by adding saline substances to raise the temperature of the boiling point.

To show the effect of pressure, water boils at a pressure of—

20·355 ins.	mercury, or	10 lbs.	per sq. in.	at	temp. of	193·3°F.
29·922 ins.	,,	14·706 lbs.	,,	,,	,,	212·0°F.
40·710 ins.	,,	20·000 lbs.	,,	,,	,,	228·0°F.
81·420 ins.	,,	40·000 lbs.	,,	,,	,,	267·3°F.
610·653 ins.	,,	300·000 lbs.	,,	,,	,,	417·5°F.

The temperatures attained by high-pressure steam explain the disastrous results seen in boiler explosions amongst those whose misfortune it has been to be exposed to it.

The graduation of a thermometer should be made on the stem. This is done by coating the stem with a thin layer of beeswax, and with a fine sharp steel point making the necesary markings, divisions, and numbers through the wax down to the glass, so that the glass is exposed at the places where the markings are required. The thermometer is then exposed for about ten minutes to the vapour of hydrofluoric acid, which marks the glass. The wax is removed when the etching is complete, with turpentine.

The thermometers required for the ordinary meteorological observations consist of a maximum, minimum, dry bulb and wet bulb thermometer, and also blackened bulb in vacuo thermometer for solar radiation, a minimum thermometer for terrestial radiation, as measured about 2 or 3 inches from the ground. Thermometers for taking the temperature of the subsoil air and water at depths of 2, 3, and 4 feet, and lastly a standard thermometer with Kew certificate for testing the other instruments with occasionally.

The maximum, minimum, dry and wet bulb thermometers should be of the best description, have the scale divided on the stem, and be furnished with a certificate as to the corrections required with each instrument at the various temperatures. The scales of the thermometer are in degrees Fahrenheit.

These four thermometers are exposed in a screen. On board ship a wall screen, consisting of a box with louvred sides is used, and on shore the one usually employed is that known as Stevenson's screen, which has double-louvred sides and front, a double roof, the upper one being about an inch above the under one, which is pierced with holes; the roof should incline from front to back and overlap the body of the screen by about 2 inches. The front of the screen opens downwards (by means of hinges placed at the bottom) away from the sun, *i.e.,* towards the north in the Northern Hemisphere, and towards the south in the Southern Hemisphere. The bottom of the screen consists of three boards so arranged that the centre one is about half-an-inch above the other two. Its construction thus allows a free circulation of air on all sides, and at the same time prevents rain or the direct rays of the sun from striking the instruments, which are fixed on uprights near the middle of the screen. The dimensions of the screen are :—length, 22 ins.; breadth, 14 ins.; height, 18 ins. It is supported on legs so as to be 4 feet above the ground, and should be painted white.

The relation of the three scales is as follows—

Between the melting point of ice, which is 32 degrees on the Fahrenheit scale, and the boiling point of water, there are 180 degrees. Between the same temperatures, Centigrade and Réaumur there are respectively 100 degrees and 80 degrees.

The three scales ∴ bear to one another the following ratios—

$$F - 32 : C : R :: 180 : 100 : 80$$
$$F - 32 : C : R :: 9 : 5 : 4$$

To convert Centigrade into Fahrenheit, multiply by 9, divide by 5, and add 32; or a quicker way is to multiply by 2, subtract one-tenth of the product and add 32.

With thermometers marked so as to show degrees Centigrade and Réaumur, if we wish to express any particular temperature taken in either of these scales, in degrees Fahrenheit, this may be done by adding together the values in degrees C and R and adding 32° to the sum.

The Maximum thermometer employed is usually one in which the index is a portion of the column of mercury detached by a minute bubble of air (Phillip's) or one in which there is a constriction between the bulb and the stem (Negretti's) in which case, when the mercury expands it is forced past the constriction, and when it contracts it is left behind, because the cohesive power of mercury is insufficient to withdraw the thread when contraction occurs as a result of diminished temperature.

The Minimum thermometer usually met with is the spirit one of Rutherford, which depends for its action upon the fact that spirit wets the glass, and the surface of the spirit is therefore concave; the free surface behaves in a different manner to the rest of the liquid by reason of its surface tension, so that if a small index of glass be contained in the fluid, it is *drawn back* by the surface of the fluid when the fluid *contracts*, but remains stationary when the fluid expands, the index will not break through the surface of the fluid, unless force be used. The instrument is set by inclining the thermometer gently so that the index is left at the surface of the spirit.

Fig. 61.—Casella's Mercurial Minimum Thermometer,

It would be well to mention a mercurial minimum thermometer devised by the late Mr. Casella, as a substitute for the instrument just described, which is intended for use more especially in hot climates where error is liable to occur from evaporation of the spirit. It consists of a mercurial thermometer, with a bulb and stem of the usual pattern, but a short distance from the bulb and in connection with the main tube is a small tube of wider bore, opening out and bending backwards, this terminates in a little pear-shaped chamber the entrance to which is larger than the bore of the main tube. The action depends in part on the adhesive property of mercury to glass *in vacuo*, and also on the fact that when two tubes are united to one bulb, the fluid will recede by contraction in the smaller, and rise by expansion in the larger. The instrument is set by inclining the bulb so that the mercury flows into the main tube and bent part of tube, but leaves the chamber empty. The instrument should after being set indicate the temperature at that time, but should the temperature rise or fall after setting, the lowest temperature which has occurred will be the temperature indicated.

The thermometers employed for measuring the intensity of solar and terrestrial-radiation have been already mentioned the one employed for solar radiation consists of a mercurial maximum thermometer having the bulb and a portion of the stem adjoining the bulb coated with lamp black, the thermometer is enclosed in a glass tube having a bulb 2¼ ins. diameter blown in such a way that the thermometer can be enclosed without touching the outer tube by means of little clips placed on the stem of the thermometer; before this outer case is sealed the air is exhausted and we then have a blackened bulb thermometer in vacuo. The reason for blackening the bulb is that by so doing you offer a surface to the rays of the sun which is a good absorber, and so prevent the loss which would occur from the reflection of heat rays from the glass forming the bulb of the thermometer, by enclosing it in the glass case the lamp black is prevented from washing off, the thermometer is also protected by it from the cooling influence of the wind. This by some is regarded as a disadvantage, but an action which we fail to regard in that manner since the black bulb thermometer is merely an instrument for estimating the intensity of solar radiation and not for taking the temperature of the air. We mentioned the fact that the glass case for this thermometer is exhausted of air, this is done so as to avoid the loss of heat which would occur if the instrument were surrounded by a medium not perfectly diathermanous, as air containing aqueous vapour would be. The black bulb thermometer is placed on a stand 4 ft. from the ground in a perfectly exposed position, such as all meteorological observatories should possess, with the bulb of the instrument pointing to the S. or S.E. if in the Northern hemisphere, and N. or N.E. in the Southern hemisphere, so that it may at all times be exposed to the sun.

The terrestrial radiation thermometer is merely a spirit minimum thermometer, usually for protection, enclosed except the bulbar portion, in a glass tube having at the open end a perforated cork through which the bulb projects. It is supported on two forked twigs so as to be about 4 inches above the ground, which where this thermometer is exposed should be covered with short grass. When the ground is covered with snow the instrument should rest on the surface of the snow.

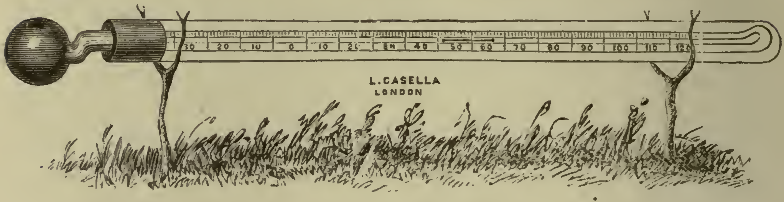


Fig. 62

Terrestial Radiation Thermometer.

These together with all the other meteorological instruments should be set after the readings have been made at the 8 a.m. observation of instruments.

In choosing a health resort it is important to know the amount of solar radiation which the places under consideration receive. We have described the black-bulb thermometer in vacuo for measuring the *intensity* of solar radiation; it remains to describe the method of recording its *duration*, that is to say, to determine the daily number of hours of bright sunshine which any particular place enjoys. The instrument usually employed is one in which the sun's rays, whenever they appear, are brought to a focus upon some material which will be charred, such as a piece of cardboard for the daily records, or a piece of wood for half-yearly records. The Campbell-Stokes Sunshine Recorder is the one usually employed, but there is a modification of this instrument possessing certain advantages over it, known as the Whipple-Casella Sunshine Recorder, which is more costly. In both instruments a record is obtained by the charring of the cardboard through the sun's rays being brought to a focus by means of a sphere of glass. The Campbell-Stokes recorder consists of a glass sphere four inches in diameter which stands on a small iron pedestal slightly cupped at the top; the glass bulb is partially surrounded by an iron frame which is moveable, which, when the instrument is placed is position, is set at an angle to the horizon corresponding with the latitude of the place, and when so set for a given place is not altered. The centre of this frame must be placed so as to face the sun at noon, *i.e.,* due South if used in the Northern hemisphere, or due North if employed in the Southern hemisphere. The frame contains three sets of grooves in one of which fits a card of size and shape suitable to the season; each card is marked out into divisions corresponding with the hours, half-hours, and quarters, so that the sunshine recorder is not only useful for establishing a record of when and for how long during the day the sun was shining, but it also serves as a sun-dial. The cards employed are of three sizes and shapes, short curved cards fitting in the upper grooves being employed in winter, broader and rectangular ones for insertion in the middle grooves at the equinoxes, and longer and more curved cards are placed in the lowest set of grooves during the summer. When placing a sunshine recorder in position, care must be taken to see that the base of the instrument and the axis of the frame carrying the card are perfectly horizontal, and it must not be forgotten that, like a sun-dial, it requires to be placed in a perfectly exposed position, so that at no

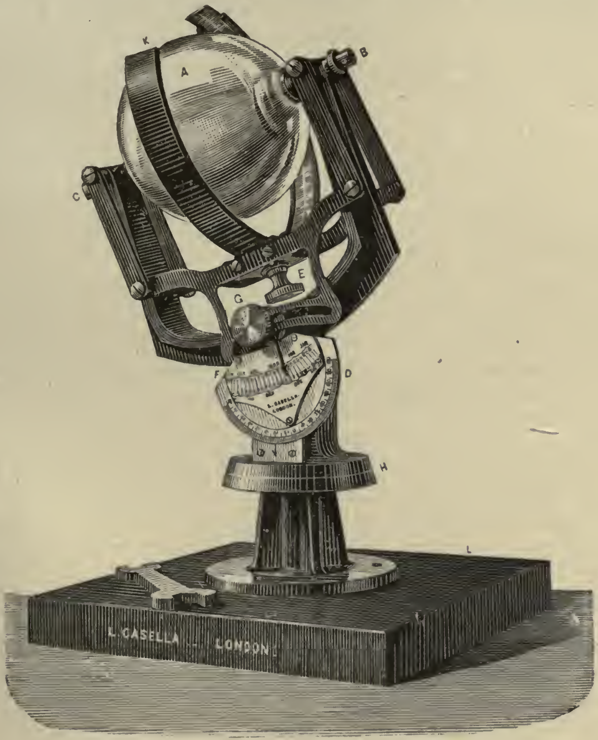


Fig. 63

THE WHIPPLE-CASELLA UNIVERSAL SUNSHINE RECORDER.

time of the day objects, such as trees or buildings, come between it and the sun. If the records are taken for the ordinary civil day, a fresh card must be placed in the frame every evening after sunset, but if the records are only required for the previous 24 hours, then the cards can be changed when taking the meteorological observations of a morning. The construction of the Whipple-Casella sunshine recorder is well shown in the accompanying illustration; it requires adjusting for latitude when first set up and then altered from time to time to correspond with the varying meridian altitude of the sun, which thus enables cards of uniform pattern to be employed all the year round. The record consists of a burnt track on the cardboard slip, obtained by means of a sphere of glass which acts as a burning glass, always in focus, as in the description of the other instrument.

The value of bright sunshine when unaccompanied by too intense heat, as a restorative to those debilitated from any cause, can scarcely be overestimated; therefore, at all stations where meteorological records are kept, the duration of bright sunshine, from day to day, should always be noted.

Effects of Heat and Cold.—Heat.—Residence in the tropics for a long period is attended with certain disadvantages. Although there are many brilliant exceptions, a prolonged residence in the tropics tends to lower the vitality and incapacitate the subjects for prolonged mental effort, and is apt to make people become listless and apathetic. Much of the mental lethargy in these cases is no doubt due to excesses and over-indulgence, notably in eating and drinking, but it cannot all be explained in this way. When a person from a temperate climate migrates into the tropics, metabolism is diminished and less food is required in consequence. Respiration is slowed and the diminution in rate is not entirely compensated for by an increase in depth, consequently less carbonic acid is evolved and less oxygen is absorbed. Dr. E. A. Parkes pointed out the difference between the amount of CO_2 exhaled by a similar individual in a temperate climate and in the tropics by expressing it in terms of carbon; if in a temperate climate 10 ozs. of carbon were expired, only 8·157 ozs. would be expired in the tropics.

High temperature such as is met with in warm climates slows the heart about 2½ beats per minute. The skin acts more freely, so that as long as evaporation from the surface in the form of perspiration is unchecked, no great discomfort will occur, but once this is interfered with, as would be the case when the air is saturated with moisture, then the effects of exposure to a high temperature are soon felt. The excess of work thrown upon the skin in those as yet unaccustomed to a high air temperature gives rise to a hyperæmic condition of the skin and prominence of the papillæ, resulting in the formation of vesicles which occasionally become pustules.

The places which are most trying to Europeans are those with a mean annual temperature of 80° or thereabouts, with a small range, that is to say, where the temperature varies little above or below the mean temperature; these places are, for the reason already stated, especially trying if, as is almost invariably the case, the air is nearly saturated with aqueous vapour.

Cold.—A moderate degree of cold stimulates the circulatory and respiratory movements, appetite increases, and the brain is capable of performing its higher functions with greater ease. Excessive cold acts by contracting the arterioles to such an extent that the circulation is so much interfered with that stasis occurs, and if the cold be continued, too long, gangrene of the parts exposed (frost bite) occurs. A remarkable feeling of languor precedes a condition of coma, which in turn is followed by delirium, with a delusive sensation of heat. People who have been exposed to the extreme cold of blizzards and died from its effects have generally been found more or less undressed, the sensation of heat due to the disturbance of the cerebral circulation leading them to divest themselves of their clothes. Extremes of cold in a *still* atmosphere have been experienced without any ill effects. In accounts of arctic exploration we read of people being exposed to a temperature of — 50° or — 60° without feeling the need of any unusual amount of clothing; simply because on those occasions the air was still, and from the low temperature necessarily dry.

CHAPTER III.

AQUEOUS VAPOUR.

The proof that the amount of vapour which a space is capable of containing is dependent solely on the temperature is shown by the following simple experiment :—

Take three clean dry tubes, each three feet long and closed at one end ; fill them with mercury, taking care that no air enters, invert them over a pneumatic trough filled with mercury, and note that the heights are equal in all three. Call one A, another B, and the third C. Leave A as a standard. Into B introduce a few drops of water, so that after a few minutes there is still some water which has not evaporated. Into C pass a little dry air so the mercury is depressed say, two inches, mark the tube at this point and then insert a few drops of water into tube C, so that there is still a little water on the surface of the mercury ; note the height of this barometer. The temperature was, for example, 59° F ; after the introduction of water into B the barometer fell say, 0·5 inches ; but in C, which contained air, there was an appreciable fall, but not equal to 0·5 inches. Now, depress tube B ; it will be found that the level of the mercury in B will always be 0·5 inches below the level of the mercury in the standard tube until all the aqueous vapour is condensed into water, and nothing but mercury and liquid water occupy the tube. Lastly, depress tube C until the mercury stands at the same level it did before the introduction of the water ; it will be seen that in order to cause the mercury in the tube to stand at the same height, or in other words, for the air to occupy the same space, C will have to be depressed 0·5 inches, which proves that aqueous vapour can exert the same amount of pressure in the presence of another gas or gases having no chemical affinity for it as it does in a vacuum. If we increase the temperature of the chamber in which the tubes are, the more it is raised the more will the mercury be depressed. It is understood, of course, that in every case sufficient water is always present to prevent it *all* being evaporated at the temperature at which the experiments are conducted, then it will be seen that for every temperature the barometer is depressed a certain amount which is invariable, and the higher the temperature the greater is the amount of depression of the mercury, or in other words, the greater is the amount of aqueous vapour present.

From this it is seen that the pressure which a vapour can exert in the presence of its liquid is dependent solely on the temperature, and the presence of another gas or mixture of gases having no chemical affinity for it does not affect this pressure in any way, or expressed differently, gases and vapours act toward one another as vacua.

A similar experiment with ether can be easily performed to illustrate the same law, and also show that at the same temperature the vapours of different substances exert different pressures. The pressure which aqueous vapour is capable of exerting at any temperature in the presence of water is therefore known as its vapour tension.

The hygrometric state of the air is expressed either as relative or absolute humidity; by relative humidity is meant the percentage of saturation existing, taking saturation as 100. Absolute humidity refers to the actual amount of aqueous vapour present in the air. Relative humidity is frequently highest when the absolute humidity is very low; thus, in winter the relative humidity may be nearly at the point of saturation, whereas the actual amount is small; whilst in summer we frequently have the air containing considerable amounts of aqueous vapour with a relative humidity far short of saturation.

Saturation may be defined as the condition of the atmosphere when it is no longer capable of containing any more (aqueous) vapour without an increase of the temperature. The temperature at which the point of saturation in a given space is reached is called the dew point.

Hygrometers are instruments for measuring the amount of aqueous vapour in the atmosphere, they may be either direct or indirect. Direct hygrometers show the dew point at once by means of a thermometer. Indirect hygrometers require observations to be made in conjunction with certain calculations.

The commonest direct hygrometers are Dine's, Daniell's, and Regnault's. Dine's consists of a metal box covered with a piece of polished glass, in contact with a sensitive thermometer, and so constructed that a flow of water through the instrument can be made to take place at will. The temperature at which dew is deposited on the outside of the glass after water has been flowing through the box is the temperature of the dew-point. Observations are checked by noting the temperature at which the dew begins to disappear, after the flow of water through the box has been stopped.

In Daniell's hygrometer we have two bulbs connected by a bent tube : one is made of blackened glass, and contains ether and a thermometer, the scale of which is visible above the blackened glass bulb ; the other bulb is made of clear glass, and is wrapped round with a little clean muslin. To use the instrument, ether is poured on the muslin bag and allowed to evaporate. Evaporation from the muslin cover, causes the temperature of the bulb to fall, any ether vapour contained within is condensed ; this condensation converts the apparatus into a retort and condenser, and the process of distillation lowers the temperature of the black bulb containing liquid ether by enabling evaporation to occur, so at length it is chilled to such an extent that the dew-point is reached, this is shown by the bulb becoming bedewed with moisture condensed on the outside. The temperature must be noted as soon as evaporation ceases from the muslin-covered bulb, for this bulb then ceases to act as a condenser, and as a result evaporation ceases to take place from the ether in the black bulb, the temperature of which now commences to rise, and the dew on its outside at length disappears. The temperature at which it begins to disappear should agree with the temperature at which it began to be deposited. The mean of the two readings is taken as the dew-point.

In Regnault's hygrometer the same result is brought about in a different way. It consists of a silver or silvered glass vessel, closed at its top except for an inlet and outlet tube which is capable of being connected with an aspirator, it also contains a thermometer and some ether. To work this hygrometer, air is drawn through the instrument, the ether evaporates and the vessel is chilled, dew is deposited at length on its outside, and the temperature at which this occurs is noted as in Daniell's hygrometer.

Of the indirect hygrometers, the wet and dry bulb thermometers of Mason is the best known, its use is restricted to warm and temperate climates ; as it is unsuitable for extreme climates, such as those of Russia and Canada. The wet and dry bulb thermometers consist of two thermometers as nearly alike as possible, the one employed as a wet bulb one, is coated with muslin, and attached to this is a small strand of wick or worsted free from grease which dips in a small vessel kept filled with pure distilled water. The dry bulb thermometer is exposed uncovered in close proximity to the wet bulb instrument. The less saturated the air the quicker will the water evaporate, and therefore the greater will be the difference between the readings obtained by the two instruments; when the air is saturated evaporation ceases, and the instruments show the same temperature. Formulæ, based on the fact that this evaporation continues until saturation is reached, have been devised for determining the dew point, and tables constructed. It is necessary to understand the nature of this process of evaporation, the theory of which is explained on page 239.

By evaporation is meant that process by which liquids and solids assume the gaseous state at their free surfaces. The term "vapour" is generally understood to mean a substance in a gaseous condition, which can exist as a liquid or a solid at ordinary pressure and temperature.

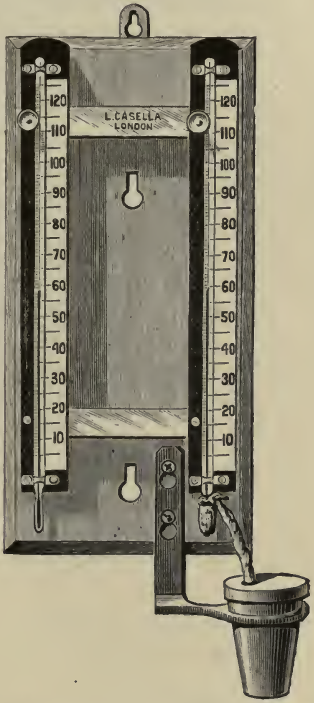


Fig. 64.—Wet and Dry Bulb Thermometer.

Tables constructed by Glaisher can be obtained, which show at once the temperature of the dew point, the relative humidity, and the amount of moisture contained in a cubic foot of air when certain temperatures are shown by the dry and wet bulb thermometers, or, if we have Glaisher's Factors and Glaisher's Tables of Vapour Tension at various temperatures, we can determine the dew point and relative humidity.

In this case we first observe the factor corresponding with the dry bulb temperature, call this F. Then take the difference between dry and wet bulb readings, call this D. Now multiply F by D and subtract the result from the dry bulb temperature, and the result is the temperature of the dew point, thus, dry bulb temperature — F D = temperature of dew point.

Having found the dew point, we next refer to the Table of Vapour Tensious given for various temperatures. Note what the vapour tension corresponding to the dew point is, call this D.P. tension. Next look for the vapour tension corresponding with the dry bulb temperature, call this dry B. tension. Then to find relative humidity we say, dry B. Tension : D.P. Tension : : 100 : X, or

$$\frac{\text{D.P. Tension} \times 100}{\text{Dry B. Tension}} = \begin{array}{l}\text{Relative}\\ \text{Humidity.}\end{array}$$

If either the dew point temperature or dry bulb temperature be intermediate between two readings given in the tables, calculate as in the following example. Say dew point temperature was found to be 59·5° then

Vap. tension at 60° = ·518″
,, ,, ,, 59° = ·500″

Difference for an increase of 1° = 0·018″ ∴ for 0·5° it = 0·018 × ·5 = ·009.″ So vap. tension at 59·5° = 0·500 + 0.009 = ·509″; or again, say dry bulb temperature was 60·7°, then vapour tension at 61° = ·537,″ and at 60° = ·518 ∴ difference for an increase of 1° at 60° = 0·019,″ and for 0·7° = 0·019 × 0·7 = ·0133, and vapour tension at 60·7° will be 0·518 + 0·0133 which = 0·5313.

The vapour tension at the dew point may be found from the dry and wet bulb readings, provided you have a table of vapour tensions (as in Appendix q.v.), by the use of Apjohn's formula, which is as follows:—

F′ = tension corresponding to wet-bulb temperature.
F″ = tension of vapour at the dew point.
D = dry bulb temperature.
W = wet bulb temperature.
87 = a constant for temperatures when dealing with temperatures above 32° F.

96 = a constant for cases when the temperature is below 32° F.

Then for temperatures over 32° F, $F'' = F' - \frac{D - W}{87}$

To take an example: Dry bulb temperature = 44° F. and wet bulb temperature = 43°.

On referring to tables we see that the tension corresponding to 43° = 0·277″.

$F'' = 0{\cdot}277'' - \frac{1}{87}$, so $F'' = 0{\cdot}277'' - {\cdot}01149''$ and $F'' = 0{\cdot}26551''$.

The formula here employed is Apjohn's in its simplest form, if greater accuracy be desired then we must allow for pressure, and this is done by multiplying the result by the pressure as found, and dividing by the standard pressure. Under ordinary circumstances the difference is so slight as to render the correction unnecessary.

In questions affecting ventilation it is always to be borne in mind that varying amounts of aqueous vapour in different portions of the atmosphere (for example, as within a room and in the outside air) affect its density considerably.

It will readily be understood how this occurs if we consider that the air is a mechanical mixture, composed (practically) of 4 molecules of nitrogen and 1 molecule of oxygen and occupying the space of 5 molecules with a molecular weight of 144; now molecules of water vapour occupying the same space will weigh 90, ∴ air is heavier than water vapour in the proportion of 8 : 5.

It often becomes necessary to calculate the weight of a given volume of air containing a certain amount of moisture so as to compare it with another equal volume of air containing either more or less aqueous vapour.

Suppose then we require to know what would be the weight of a cubic foot of air with a temperature of, say, 60° F. and with the dew point temperature 56° and barometric pressure 29·5 inches?

We know that a cubic foot of dry air at 32° F. and 30 inches pressure weighs 566·9 grains, and that the volume varies inversely with the pressure and increases $\frac{1}{273}$ for every increase in temperature of 1° C., or $\frac{1}{491}$ for every 1° F.

∴ to find density Δ

$$\Delta = \frac{B}{30} \times \frac{459 + 32}{459 + 60} \times 566{\cdot}9 \text{ grains}$$

This would be the weight of the air if there had been no moisture present, but the dew point was 56° F., and vapour tension at 56° = ·449 inch, so that the pressure at the time of observation = B — $\frac{5}{8}$ of vapour tension.

∵ Dry air is to aqueous vapour as 8 : 5, so the pressure will be dimished by $\frac{3}{8}$ of the pressure exerted by the aqueous vapour present, so to find the weight of a cubic foot of moist air at B pressure when dew point = 56° F., and vapour tension ∴ = ·449 inch, we have—

$$\Delta = 566{\cdot}2 \times \frac{B - \frac{3}{8} \times {\cdot}449}{30} \times \frac{459 + 32}{459 + 60}$$

= 523·8 grains. A cubic foot of moist air ∴ weighs less than a cubic foot of dry air at the same temperature by reason of the loss of density due to the barometric pressure being reduced by the loss of $\frac{3}{8}$ of the existing vapour tension.

Saussure's hygrometer is an instrument for indicating the relative humidity of the air by means of an indicator which points to a figure on a scale showing the percentage of saturation, it depends for its action upon the fact that a hair deprived of all grease, elongates and contracts according as the air is moist or dry. The mechanism of the instrument is as follows:—A hair free from grease is made fast at one end, whilst the other passes over a pulley, with which is connected a lever acting as the index; the end passing over the pulley is fastened either to a slight spring or supports a weight. When the instrument is first made, it is so arranged, that with a saturated atmosphere the pointer stands at 100, and with an absolutely dry atmosphere at 0.

Humidity has perhaps more to do with the healthiness of a climate than anything else. A temperature, which in a dry climate is not at all ill-borne, becomes unbearable when the relative humidity is high. Air which contains little or no aqueous vapour is practically aseptic. Desert air owes it aseptic property to the absence of aqueous vapour. Mountain air which is so invigorating contains very little moisture. Certain affections, such as bronchitis and influenza, are relieved by a moist atmosphere, but catarrhal conditions and hæmorrhagic phthisis suffer considerably from too much moisture in the air. Dr. Williams *(Treatise on Hygiene)* mentions the case of a patient of his who was suffering from advanced phthisis and was staying in the South African Kala Hari Desert, the air of which was so dry that the difference between the dry and wet bulb thermometers amounted to 25° F., on one occasion a heavy shower of rain with a saturated atmosphere came on suddenly, and gave rise to a severe attack of hæmoptysis on the part of the invalid.

Chemical hygroscopes are capable of great accuracy, for example, if a known weight of dry calcium chloride ($CaCl_2$) be contained in a tube, and a known weight or volume of air be made to pass over it, the increase of weight in the tube will show the amount of aqueous vapour present. In practice such a method is seldom, if ever, resorted to.

The molecular theory has already been alluded to in a previous chapter to explain the gaseous, liquid and solid states, for by it we assume that liquid water consists of a number of particles vibrating with different velocities in all directions, and so acting on one another as to constantly interfere with each others movements. Vapour in like manner is supposed to consist of particles moving with various velocities but not interfering with one another until they come very close together. The velocities of both sets of particles increase as the temperature rises. In this theory it is also assumed that there is a force on either side of the boundary between liquid and gas, which tends to prevent the escape of particles from the liquid. If a particle within the liquid is moving with sufficient force it will be able to burst through the boundary and will then be free and become a particle of gas. The higher the temperature, the greater will be the velocity of the particles and the greater will be the number making good their escape. At the same time some of the particles outside will be moving in the direction of the liquid, and be forced through and become liquid, the rate of evaporation therefore will depend upon the extent of the surface exposed and also on the number of particles of the gas above the liquid. And it can be proved by experiment, as already described, that the extent to which this process can proceed depends solely on the temperature, or in other words, that gases and vapours of different natures act towards one another as vacua (Dalton's law). When the air or space is saturated at any temperature it merely means that condensation and evaporation are equal, and that the loss is counterpoised by the gain.

The rate of evaporation depends on the relative humidity of the air, conditions therefore which increase the capacity of the air for aqueous vapour, increase the rate of evaporation; these are movement of the atmosphere, a high and increasing temperature, and absence of large quantities of water. How these act is too obvious for us to point out. The rate of evaporation affects health very considerably; by means of evaporation we are enabled to withstand the effects of high temperatures, a moderately high temperature and a low rate of evaporation being extremely depressing, whereas temperatures much higher and a dry state of the atmosphere can be borne without ill-effects.

When water evaporates a large amount of heat is used up in effecting a change of state from the liquid to the gaseous state, the heat being stored up or rendered latent, ready to be again given out when condensation takes place, one grain of water in evaporating uses up or renders latent as much heat as would raise 960 grains of water through 1° F.

Since evaporation uses up or renders latent a large amount of heat, it follows that places near the sea, or wherever there is much water, are much cooler in summer than places in corresponding latitudes where there is no large water surface in the vicinity. When the air becomes colder the heat rendered latent by evaporation is again set free on condensation, and the air is in consequence warmed; so large expanses of water tend to prevent excesses in either direction.

The amount of evaporation which takes place yearly at a place is a matter of considerable importance in determining the amount of water which will be yielded by a given area after allowing for loss by evaporation. By Pole's formula we can determine the probable daily yield of the collecting area.

E = annual loss of water by evaporation expressed in inches. Rm = average rainfall of a long series of years. $\frac{4}{5}Rm$ = estimated average of the 3 direct consecutive years. A = area in acres of collecting ground. Then $62\,A \times (\frac{4}{5}Rm - E)$ = yield of water per one day, and this multiplied by n gives the amount for n days. The constant 62 is derived as follows: 1 acre yields with 1 inch of rain 22,635 gallons of water, and since the amount indicated by Rm refers to inches of rainfall *per annum,* the value 22,635 must be divided by 365 if we require a constant which will show amounts per diem, so

$$\frac{22635}{365} = 62$$

For example, it is required to know the amount of water which will result from the storage of ten days' rainfall when the mean annual rainfall is, let us say, 25 inches, in which case $\frac{4}{5}$ of 25, which equals 20, will be the estimated average of the three direct consecutive years; the estimated loss from evaporation is equal to 10 inches of rainfall, and the area of the collecting ground is 100 acres; then the answer in this case will be:—

$$62 \times 100 \left[\left(\frac{4}{5} \times \frac{25}{1}\right) - 10 \right] = 62000,$$

i.e., the number of gallons which will result from the storage of one day's rainfall, and therefore, for ten days it will be 620,000 gallons.*

As a rule the evaporation in the higher latitudes is less than the rainfall, the balance between evaporation and rainfall

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* A gallon of water occupies 277·274 cubic inches, or 1 cubic foot will hold 6·232 gallons.

being restored by the excess of evaporation over rainfall which occurs over the sea in low latitudes.

There are numerous instruments devised for determining the amount and rate of evaporation, many of them working upon different plans. For example, Wild, of St. Petersburg, weighs a given mass of water by a self-registering weighing apparatus, a record being obtained automatically every 10 minutes, which shows rainfall, rate of evaporation, and weight of snowfall.

Richards has an apparatus which consists of a pair of scales, one of which supports a basin of water, the instrument is counterpoised when set, and any alteration occurring afterwards is recorded by a pen on a revolving drum.

The Piche evaporimeter consists of a graduated tube, closed at one end and filled with water, the other end is covered by porous paper, when required for use it is turned so that the paper end is lowermost, water is evaporated from the paper and the paper receives a fresh supply constantly from the water contained in the tube. The alteration in the level of the water in the tube shows the amount of evaporation which has occurred.

Lamont's Atmidometer or Atmometer is another evaporimeter, which consists of a pan exposing a known area, this is connected with a cylinder to which is attached an indicator which can be moved up and down a graduated scale. The scale is set with the pointer at zero and water is poured in until it is flush with the surface of the pan, the instrument is left for a given time, after which, the water has fallen below the level it originally stood at, to a greater or less extent, according to the rate of evaporation. To obtain a reading, the screw working the cylinder is turned until the water is brought up once more flush with the level of the pan and the pointer will now be found to have traversed a certain distance on the scale, and this indicates the amount of evaporation which has occurred.

Aqueous vapour influences solar and terrestrial radiation very considerably, but hardly to the extent to which at one time it was credited, since it is now known that dust and also water, in a minute state of subdivision, perform a very important share of the work in checking radiation.

Things are often insufficiently appreciated until they are lost, thus it is when aqueous vapour is present only to a slight extent, that we are able to form an opinion of its action, for it is then we suffer from the effects of solar radiation by day, and terrestrial radiation by night; the protecting veil is then removed and we have an extreme range of temperature. Good examples of this action are afforded by the air in the Sahara Desert and in the Arctic regions, both of which are characterised by a remarkable absence of aqueous vapour; in the former case the heat by day is intense because there is no protecting veil to keep off the heat rays, and at night the cold is intense because there is no protecting covering to prevent heat radiating off into space. Likewise in the Arctic Regions, the heat in the sun may be sufficiently powerful to melt the pitch in the seams of the deck, whilst out of the sun the cold is many degrees below freezing point.

Aqueous vapour present in the air, as explained further on, acts by absorbing certain rays from the sun, producing in a spectrum black lines or bands in the yellow; it is found that the breadth of this set of dark lines, known as the *rain-band*, is proportional to the amount of aqueous vapour contained in the air, and this band can be observed by means of a a spectroscope as illustrated (*fig.* 65). Aqueous vapour is also capable of retaining or absorbing a considerable amount of the heat waves from the sun, these waves can readily pass into an atmosphere containing aqueous vapour, but less readily pass out, so that the heat is as it were entrapped, just as it is by the glass of a green-house, which lets it pass in but interferes with its passage out.

Fig. 65
RAIN-BAND POCKET SPECTROSCOPE.

In regard to this absorption of certain rays from sunlight, certain vibrations or sound waves of certain length produce certain definite sounds or musical notes, different wave-lengths of light in what is termed the ether produce different colours. The vapour of any substance when set in motion, vibrates at a certain rate and has wave-lengths of a certain definite length, which can be set in motion by vibration of waves of the same amplitude.

Now, radiant energy in the form of light is made up of rays of very varying wave-lengths, and in passing through the vapour of any substance, or substance in the gaseous state, this vapour will be set vibrating by those constituent rays whose wave-lengths coincide with its own, and consequently those rays passing in and possessing the same wave-lengths, and only those will be absorbed. This can be expressed tersely by saying a body absorbs the same kind of rays as it gives out. A beam of white light possesses rays, some of which vibrate in unison with those of aqueous vapour when set in motion; if therefore they pass through air containing a greater or smaller amount of aqueous vapour, a greater or smaller amount of these waves will be absorbed, hence the absorption of those waves whose wave-length correspond with that of aqueous vapour and the formation of the band known as the rain-band.

In the Solar Spectrum, as we have already said, the different colours are produced by rays of different wave-lengths, and the spectrum sorts out the rays according to their wave-lengths, thus the shortest visible light waves are the violet ones with a length of $\frac{1}{67000}$ of an inch, and the longest ones are the red with a length of $\frac{1}{26000}$ of an inch; beyond the red, are the long heat rays which are invisible, and beyond the violet are the equally invisible actinic or chemical waves.

The absorption band produced by the presence of aqueous vapour is situated in the yellow, close to the Fraunhofer's line D, and on the red or left side of it.

Aqueous vapour is capable of being condensed under varying conditions and into various forms, such as—(1) dew, (2) hoar frost, (3) fog, (4) mist, (5) cloud, (6) rain, (7) snow, (8) hail.

(1) Dew. Dew is deposited wherever the air is so reduced in temperature that it is no longer capable of holding the same amount of aqueous vapour as it contained previously, the deposit taking place on objects in contact with the earth. The point when saturation is reached is called the dew-point. If the dew-point is above the temperature 32° F or 0° C, dew is deposited in the liquid form, but if the dew-point be below 32° F, it is deposited as small ice crystals and known as (2) *hoar-frost*.

The circumstances affecting the deposition of dew or hoar-frost, indicate pretty clearly the cause of the deposition. Dew is deposited on *cold still* nights when the sky is *clear* and there is *not* an *excess* of *aqueous vapour* or dust particles in the air. The air is cold when there is nothing to check radiation of heat into space.

When the air is *still*, objects cooled by this radiation remain cold because the air being still, warmer portions of air are not brought up which would thus warm the objects chilled. The air is *clear*, on clear nights radiation is not checked, on a cloudy night the minute spherules of water floating in the air intercept the heat, prevent it passing into space, and radiate back nearly as much as they receive.

If the air contains an excess of aqueous vapour, dew is interfered with because so much heat is given out on condensation, that very little fall in the temperature results; also aqueous vapour, as we said before, interferes with radiation into space. Lastly, dew itself, when deposited, forms a blanket which tends to check materially further loss by radiation of the earth's heat into space

Dew is mostly deposited on good radiators and bad conductors. This explains why sticks or vegetable material condense more than stones; the stones radiate freely, but being good conductors compared with sticks, receive heat from the ground on which they lie.

A phenomenon known as glazed-frost occurs when a warm moisture-laden wind suddenly sets in after a hard frost, when all the ground and objects in contact with it are far below the freezing point, the aqueous vapour is then directly frozen as it is condensed, and a solid mass of ice results.

Before proceeding to explain the phenomena of fog, mist, cloud, and rain, it is important to grasp the conditions under which aqueous vapour is condensed in each of these cases; the temperature at which condensation and evaporation occur is dependent upon the existence of a free surface or a surface at which a substance is free to change its state. The terms, melting point of ice and boiling point of water, as usually understood, imply the existence of a free surface, as in the absence of these, the temperature differs widely from those at which the phenomena occur under ordinary circumstances. For example, ice has been raised to 180° C, and water has been cooled far below 0° C without freezing, and again, in the absence of a free surface, the temperature of boiling water has been raised far above 100° C. Dust particles floating in the air afford the required "free surfaces." Air free from dust and containing aqueous vapour, can be cooled far below the dew point without condensation occurring, as shown by Aitken's experiments, in which he allowed steam to pass into exactly similar receivers, but which contained respectively ordinary air and air deprived of its dust particles by filtration through cotton-wool. In the former case a cloud at once formed, whereas, it the one containing dust-free air, no condensation occurred. The dust particles act as nuclei upon which aqueous vapour is enabled to condense, and Aitken was able to show that, according as the number of dust particles is great or small, so the size of the globules of water vary inversely; the greater the number of dust particles the smaller the globules. The next paragraph explains how it is that some globules appear to float in the air as is the case of fog, whereas, others fall to the ground as we see in rain.

(*3*) *Fog* is a condition in which water in a very minute state of division floats at the level of the earth and does not wet substances with which it comes in contact. The water particles are in such a minute state of division and offer so much resistance to the air that they are either suspended, or at any rate fall very slowly. Practically any substance, however dense, if divided sufficiently can be made to float for a time in the air, or at all events fall very slowly, this accounts for the cases where mineral dust from volcanoes has been known to remain suspended for comparatively long periods.

Mill, in *The Realm of Nature,* p. 109, gives a good example which clearly explains this:—1 cube of stone 1 inch in the side offers an area of 6 square inches. Cut this into 10 slices $\frac{1}{10}$ inch and each slice into 10 bars, and each of these into 10 cubes, then we have 1000 cubes each, $\frac{1}{10} \times \frac{1}{10}$ inch $\times 6 = 60$ square inches for the whole 1000; cut each of these into 1000 cubes and we have a million cubes each, $\frac{1}{100} \times \frac{1}{100} \times \frac{6}{1} \times \frac{1000000}{1} = 600$ square inches, from this it is not difficult to understand how the same mass comes to offer a much greater surface the more it is divided and sub-divided, so that in this case, as Mill says, the "air brake is applied to 600 square inches instead of 6 square inches before division."

Fogs are formed whenever the dust particles are numerous and air containing a considerable amount of moisture, is cooled down to such an extent that condensation takes place. As we said before, the more numerous the dust particles are, the smaller will be the particles of water condensed. If these particles contain tarry matter, as they do when they are the result of the combustion of coal, as in our towns, each particle, when condensed, will receive on its surface a coating of tarry matter, which will prevent it from evaporating when the temperature rises; in this respect a town fog differs from a country fog in that it does not disappear rapidly on entering a warm room. but gradually settles down leaving a black coating on all objects on which it alights.

Fogs never form in windy weather, as the condensed particles are blown away as soon as they form. London owes its fogs to the fact that it lies in a hollow, through which the river Thames flows, it is surrounded more or less on all sides by hills, and has an enormous amount of dust particles floating about, the result of the large amount of smoke which is being constantly poured into the air from countless chimneys. On a still winter's day a large number of dust particles are ready to afford free surfaces for condensation to air at or near the point of saturation, if now colder and equally saturated air flows down from the surrounding hills into the valley, the dew point is reached, condensation occurs, and a fog results.

Sea fogs often occur on our coasts in summer because the air over and near the sea is charged with moisture, and frequently a cold breeze sets in and condensation occurs. They never extend far inland, because over the land, where the air is drier this condensation does not occur.

Off the Grand Banks of Newfoundland, the warm gulf stream flows, with warm moisture-laden air above it, whilst flowing south alongside the northern edge of the Gulf Stream is the Cold Current (Davis Strait Current) the air over which is considerably colder, where the cold and warm masses of air meet we get condensation and fog.

The line of separation between the Davis Strait Current flowing down the coast of America, over the Newfoundland Bank inside the Gulf Stream is called the "Cold Wall."

(4) Mist is formed when the air next the earth becomes heated or charged with aqueous vapour and so being of diminished density rises and encounters a cold stratum of air which causes a condensation of the aqueous vapour on dust particles floating in the air. Mist consists of minute drops of water, somewhat coarser than those met with in fog; the sudden disappearance of mists is due to the air in which the mists float ceasing to be saturated either from an increase in its temperature or from mixture with drier air.

CHAPTER IV.

AQUEOUS VAPOUR (CONTINUED).

(5) *Clouds* consist either of minute drops of water or ice particles, floating at a considerable elevation. These particles are not strictly floating, but always falling to a greater or less extent, and at length reach a portion of the atmosphere where the temperature is sufficient to cause the drops to evaporate and so become invisible; thus clouds never form below a certain level, called the cloud-line, which varies with the temperature, which again depends on season, latitude, and the various circumstances affecting air temperature. The cloud-line in Great Britain is about 1,400 feet. In warmer climates it is anything up to about 9,000 feet.

Clouds are produced in various ways; according to Ley, in his work entitled "Cloudland," there are four chief ways, viz., by

(1) Inversion;
(2 and 3) Interfret and Reversed Interfret;
(4) Inclination.

By the first term is meant any movement which tends to invert the atmosphere, *i.e.,* carry the lower strata into the upper regions. The circumstances which will affect this inversion most thoroughly, are those which will render a limited portion of the atmosphere specifically lighter than the air around it, these are the heating of a limited portion of the atmosphere with, as usually occurs, an addition of aqueous vapour, both of these render the air specifically lighter than those portions of the air in which these changes have not taken place. It will be readily understood how much lighter air containing aqueous vapour is than dry air, when we consider that the proportional weight of a given volume of water vapour is to that of an equal volume of dry air at 60° F. and 30″ Pressure as 0·622 is to 1·7.

As air ascends it becomes cooler, because (a) by ascent it becomes more removed from the heated earth; (b) the higher it ascends the less pressure it experiences, and consequently, being under diminished presure, it expands and loses heat in virtue of the work done in the process of expansion. Air, under ordinary circumstances, loses 1° F.

for every 270 feet ascended. Now, in winter it often happens that when the weather is very cold, the air is actually colder near the earth than it is at an elevation of many feet (as we know occurs in cases where an "up-bank" thaw is seen).

In summer, the air near the earth is often very much heated, and whilst the air at a comparatively small elevation is considerably colder; therefore, in the two cases of winter and summer air-temperature, we have conditions quite opposite, and it is, thus, easy to see that an ascending current in winter becoming cooler and cooler as it ascends, soon reaches a place where it is actually colder than the surrounding atmosphere, it therefore falls back, whereas in the summer-time, it must rise to a great height before it can be heavier than the surrounding atmosphere. Suppose that at length it has risen to a height when the dew point is reached, condensation occurs and the latent heat thereby evolved gives the air an additional impulse. We can understand this process going on and on until there is no more aqueous vapour left to condense, and then the air falls down on the outside of the heated column. At the first place where condensation occurred we have the lower limit of the cloud, and where condensation ceased to occur we have the upper limit.

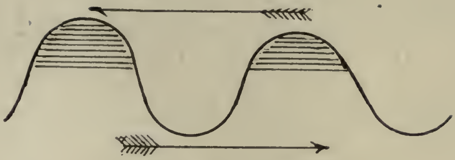
A cumulus cloud is the typical inversion cloud. A cumulus cloud on a small scale forms above the funnel of a locomotive engine when steam is discharged: just above the funnel there is invisible aqueous vapour, higher up where the dew point has been reached, and condensation has occurred, we have the visible cumulus cloud, resembling masses of cotton wool.

Interfret and Reversed Interfret are both cases where a warm and cold current flow, either in opposite directions or at different rates of speed in the same direction.

In the case of the Interfret the cold current is uppermost, and in Reversed Interfret the warm current is uppermost.

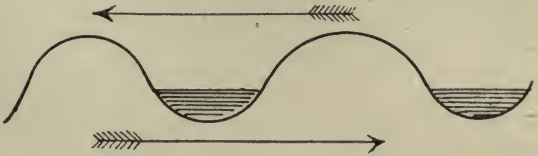
It has been shown by Herr von Helmholtz that when two currents of air of different density, or different temperature, are in contact, and flowing either in opposite directions, or at different rates, waves are produced. These waves are of great size, and the distance between two contiguous crests may be reckoned in kilometers. If sufficient aqueous vapour be present, condensation will occur in the part of the wave which is most exposed to the chilling influence, and the air-waves become visible. On reference to the accompanying diagram, the parts where condensation occurs in each case are shown by the shaded lines.

Fig. I.—COLD CURRENT.



WARM MOIST CURRENT.

Fig. II.—WARM MOIST CURRENT



COLD CURRENT.

Fig. 66

It will be seen that in Fig. 1, that is Interfret action, condensation occurs in the crests of the waves.

In Fig. II., reversed Interfret, condensation occurs in the troughs of the waves.

Waves of air present after this condensation has occurred have the appearance of parallel billows, and the Germans describe these as *wogen wolken* (wave-clouds).

An example of an interfret or reversed interfret cloud is the stratus cloud (which is, more or less, stratified in appearance).

When the regular parallel billows, produced between the strata of air, have met other currents having different velocities and densities, they become broken up into smaller detached portions, often, more or less, lozenge-shaped.*

(4) The fourth case, or that of Inclination; in the upper region of the atmosphere condensation has occurred, probably by interfret action: ice crystals have formed, and these falling by gravity as they constantly meet with currents moving more slowly than where they have come from, tend to lag behind. This viewed *en masse* gives a spiral arrangement. As the particles descend they encounter warmer and warmer currents, and eventually are melted and evaporated. This action accounts for the formation of those delicate feathery clouds high up in the sky known as cirrus clouds (mare's tail clouds).

Clouds are often composed of several varieties of cloud; in other words, they are compound. Thus we have cirro-cumulus, cirro-stratus, and cumulo-stratus.

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* *Nature*, Vol. LV., p. 325.

The cirro-cumulus are known popularly as mackerel-scales. They are also often compared to a flock of sheep lying down. Their usual height above the earth is about three miles.

A mixture of cumulus and stratus is known as the nimbus, or rain cloud.

Clouds are often classified as upper and lower clouds. The upper clouds, composed probably of ice particles, are the cirrus, cirro-cumulus, and cirro-stratus, seen very high up, at an elevation of five miles or more. The cumulus is often not more than three-quarters of a mile up; and the stratus, resembling a piece of lifted fog, are often only about half a mile up.

Cirrus clouds overspreading the sky often appear like the shadows of coming events, and foretell the approach of an area of low pressure with its accompanying phenomena. They are due to an overflow in the upper regions of the sky of heated air.

Clouds are the sky-signs of mariners, by which changes of weather are often foretold.

Admiral Bedford, in the *Sailors' Pocket Book*, gives the interpretations of these sky-signs.

From clouds we pass on to (6), *Rain,*, and, as we have previously explained, if in an atmosphere containing much aqueous vapour, there are comparatively few dust particles to serve as nuclei for condensation, we find that each particle is the means of condensing a good deal of moisture, and the result is drops of water of such a size that they fall because they do not meet with sufficient resistance to prevent their fall.

Rain drops do not grow appreciably in the act of falling as was at one time believed, because, were that the case, their temperature would be considerably raised by the condensation. Sir John Herschel proved this by showing that since the latent heat of steam is about 1000° F. or 537° C. at standard atmospheric pressure, which, expressed in degrees F. is 998°.6, it is evident that if they receive an increase in weight = 1 per cent. from vapour condensed, their temperature must in consequence be raised 10° F., and if they gain say 10 per cent. their temperature would be raised to 100° F.

The circumstances which will bring about the condensation alluded to in a previous paragraph are those which will carry a warm or comparatively warm and moisture-laden current into higher and colder parts of the air, such as an "inversion movement," or when a warm moisture-laden current of air strikes the cold earth, or is forced to ascend the side of a mountain or mountain range, where in addition to the cooling influence of contact with the cold mountain side, it is cooled by its forced ascent into regions where the air is colder and pressure is less.

Rain is collected in a rain gauge and measured in a measure graduated proportionately so as to show the yield in inches of depth. An inch of rain means that rain has fallen over a given area to such an extent that if this area was perfectly level and bounded by vertical sides to prevent the water from flowing off, then everywhere throughout this area there would be water to the depth of one inch as the result of this rainfall, thus an inch of rainfall over an acre of land means 22,635 gallons of water which weighs 101 tons, 3 qrs., 26 lbs. It will be seen, that given the area of your collecting surface and knowing that a cubic inch of water at 62° F. weighs 252·216 grains, it is not difficult to calculate the amount of water which each inch or fraction of an inch represents, for example, a circular gauge the diameter of which is eight inches, has a collecting area of 50·2656 square inches so that one inch of rainfall yields with it 50·2656 × 252·286 grs. of water.

Now 1 oz. water weighs 437·5 grs. $\therefore \dfrac{50{\cdot}2656 \times 252{\cdot}286}{437{\cdot}5} =$ number of ounces yielded by 1 inch of rainfall, which = 29·019 ozs., $\frac{1}{10}$ which = 2·9019 ozs., $\frac{1}{100}$ which = 0·29019 oz. and so on.

The making of a rain gauge is a matter of extreme simplicity, a funnel of known diameter, a bottle and a measure glass being all that is required.

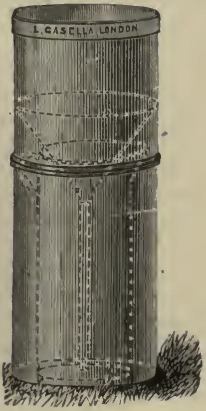

Fig. 67
RAIN GAUGE.

Fig. 68
MEASURE GLASS FOR RAIN GAUGE.

Circular rain gauges are employed in preference to rectangular ones, because they are less liable to become indented.

The exposure of a rain gauge is important: it should be placed in an exposed position on the earth, so that the rim is perfectly horizontal and one foot above the ground.

The placing of a rain gauge on a wall or on the roof of a house is objectionable because eddies caused by the deflection of the wind are liable to prevent the rain from entering the gauge when there is a strong or even moderate amount of wind.

The number of days on which rain falls is often of more importance from a hygienic point of view than the total rainfall.

For example, if in the month of September there was a total rainfall of 3 inches, the result of rainfall occurring on three days, it means that there were 27 days on which no rain fell, and were therefore probably fine and bright, which would be better than a month, during which on 30 days there was a rainfall of 0·05 inch each day, making a total of only 1·5 inches, for in all probability on most of the days during that month, the sky would be clouded and the sun obscured.

A day is counted a "rainy day" when the total rainfall recorded amounts to 0·005 inch.

When the condensation of aqueous vapour occurs at a temperature below 32° F. it takes place in the form of ice-crystals which cross each other at an angle of 60° and arrange themselves into six-pointed stars or hexagonal plates, forming (7) *Snow*. These crystals become linked together to form snow-flakes, which are loosely packed ice crystals entangling much air, the size of the crystals vary with the amount of moisture in the air at the time of condensation, the greater the amount of moisture, the larger the flakes. When the air is very dry, the flakes are so small as to be practically only snow dust, so fine that they penetrate everywhere, as occurs in the American blizzards, where the fine snow dust, flying before a strong wind, finds its way into every crack or crevice. In regard to blizzards, the late Hon. Ralph Abercromby (in *Weather,* p. 223 second edition) shows that they are caused by the passage of the rear of a cyclone or V-shaped depression close to an area of high pressure, the result of which is a sudden sharp fierce wind blowing over a frozen continent many degrees below zero. These blizzards soon prove fatal to life unless shelter be speedily obtained. No clothing can prevent the penetration of the blinding dust of finely powdered snow. Abercromby says that—"In almost every case the victims are found to have begun to strip themselves. When the body is nearly reduced to an icicle, only a very little blood continues to circulate languidly through the brain, then delirium sets in with a delusive sensation of heat, under the influence of which the traveller begins to divest himself of his clothes."

It is to the loose texture of snow that it owes its dazzling whiteness, reflection and refraction occurring over and over again from the countless ice-particles and air closely intermixed with their widely different refractive indices give rise to the opaque white color, and it is this looseness of texture which causes it to be such an imperfect conductor of heat, preventing terrestrial radiation, and reflecting and radiating off any heat which might reach the earth from the sun.

Looseness of texture explains the paradoxical action of snow, which keeps the air cold and the earth warm. It keeps the air cold by preventing it from coming in contact with the warm earth, which is the only way in which the air is heated, heat being passed on from one part of the air to another by convection. It keeps the earth warm by preventing loss of heat from it by radiation which on clear still nights when the ground is not protected by snow, we know to be considerable.

A foot of snow is approximately equal to one inch of rain. Where the mean temperature is always below 32° F., snow falling at such a place does not melt, and the level at which snow is permanently present is called the snow-line, the snow line is at sea-level in the arctic regions. and some 16,000 feet at the equator, and at varying heights between these limits which depend chiefly but not entirely on latitude.

(8) *Hail* is met with in two forms, which are known as the true and the soft hail. True hail is a phenomenon seen most frequently in summer, soft hail is only met with in winter or early spring. True hail shows a structure which may be compared to a calculus in that it always contains a central nucleus around which are seen, on making a section, various layers of clear and opaque ice (the opaque ice owes its opacity usually to the presence of small air bubbles or vacuoles) whilst some of the outer layers have a naked eye appearance of radiating lines, which, however, on microscopic examination, are not visible.

True hailstones are usually associated with heat thunderstorms, it is not certain whether the hailstones are produced by electrical attraction and repulsion of ice particles from one stratum of the atmosphere to another where alternate condensation of water on their surface and congelation into ice occur, or whether the hailstones are made to move from one part of the atmosphere to another by a whirlwind action, or by being caught alternately in ascending and descending currents of air. Whichever way hailstones are produced, there is always one circumstance in common, and that is there has been formed a powerful ascending current of air, the result of the heating of a localised portion of the earth's surface. There must also be a portion of the atmosphere where there is a large amount of aqueous vapour, and also some portion of the atmosphere where the temperature is below 32 deg. F. and all these conditions must be met with in portions of the atmosphere quite adjacent to one another.

Hailstones on the Continent are often of great size; hailstones of two pounds weight* are by no means unknown, and it is these large hailstones which are so destructive to flocks and crops.

The Burgomaster of Winchsch-Freistritz, Lower Steinmark, Austria, owns extensive vineyards on the southern slopes of the Bacher Mountains, which cover an area of about two square miles, and are commanded by six prominent hills. It occurred to the Burgomaster that if the thunderclouds, such as were known to lead to hail-storms, could by any means be dispersed the hailstorms would be averted, and accordingly on each of the six prominent hills overlooking his vineyard he placed 10 mortars capable of firing a heavy charge of powder, and when a storm threatened, each of the mortars was charged with 120 grammes of powder ($4\frac{1}{4}$ ozs.) and fired simultaneously, on each of the six stations, these 60 mortars were fired repeatedly in quick successive volleys, with the result that soon a funnel-shaped opening appeared in the clouds surrounded by rings which appeared to be opening out the cloud, and soon the clouds dispersed and no thunder or heat storm appeared.

On six occasions these tactics have proved successful, which goes far to prove that explosions tend rather to prevent than to produce rain when large cumuli are floating over the place where the explosions occur.

Soft hail, as we said before, is met with in cold, dry weather, such as often exists in winter or early spring; it is known in Germany by the name of *graupel*. Soft hail resembles small, loosely made snowballs, is usually in shape similar to a pegtop, and it is thought to be formed by the adherence of ice particles to one another in a deep ice cloud, as they descend they gather more ice and being sufficiently

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* A case is recorded in France of a thunder-storm which occurred on the 26th and 27th August, 1894, during which hailstones weighing 2-lbs. fell and killed many birds and even sheep.

dense to overcome the resistance of the air they fall. Soft hail shows none of the stratified formation seen in true hailstones.

In describing a hail-storm, observers should note the sizes of the hailstones, an average weight is easily obtained In the following manner * :—

Gather a certain number of hail-stones, note the number, and place them in a rain-gauge glass, and note the amount of water yielded when they are melted. If now we measure them in the measure glass graduated for an 8-inch gauge, we proceed as follows :—Each ·01 inch rainfall measures 0·29019 ounce, which = 126·958 grains, say in round numbers 127 grains. The number of hundredths of an inch of water yielded, by the stones multiplied by 127 and divided by the number of stones, gives the average weight of the hailstone. *e.g.*, suppose 10 stones yield 0·06 inch of water in 8-inch guage glass, and it is required to find the average weight of the hailstones, then $\frac{6 \times 127}{10} = 76{\cdot}2$ grains is the average weight of each stone.

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* Symon's monthly *Meteorological Magazine*, Vol. XIV., 1879.

CHAPTER V.

WIND.

When air moves in the open without artificial cause it is known as wind, this distinguishes it from currents set up by fans or induced by other mechanical or artificial means.

Wind is caused by differences in atmospheric pressure, which are produced by certain portions of the atmosphere becoming specifically lighter than neighbouring portions, they therefore rise and flow away in the higher portions of the atmosphere, and the heavier air is driven in on all sides until the pressure is equalised.

The greater the difference in pressure, the stronger will be the wind. This is often expressed by saying that the force of the wind is proportional to the closeness of the isobars, isobars being imaginary lines connecting places of equal barometric pressure, and drawn in series for every 0·1 or ·01 of one inch of pressure, just as contour lines are drawn on ordnance survey maps to show differences of level.

Differences in pressure between any two places are described as a gradient of a certain steepness, just as differences in level between any two places, for example as on a railway line, are spoken of as a gradient of a certain amount. In engineering the vertical and horizontal units are of the same kind, *e.g.,* 1 foot in 1000 feet, whereas in meteorology the vertical unit refers to the height of the barometer, and the horizontal unit is in geographical miles.

The English and the Continental barometrical gradients are practically identical, thus :—

The English vertical unit is 0·01 inch pressure, and the horizontal unit = a quarter of a degree or 15 geographical miles which = 17 statute miles. The Continental vertical unit is 1 millimeter = 0·03937 inches (which is practically 4 times ·01 inch), and the horizontal unit = 1°, which = 60 geographical miles, which is 4 times the English horizonal unit.

Now to give an example, if the barometer at a certain time stands at 30·05″ at London Bridge and 30·000″ at Portsmouth, which is 85 statute miles distant from London Bridge, then the difference for 85 statute miles which = 75 geographical miles = ·05″, and for 15 geographical miles it = ·01″. So that between London and Portsmouth we should say that there is a gradient of 1° for S.E. winds, the isobars running from N.W. to S.E.

Had the difference in pressure been 0·025″ it would then have been 0·005″ for 15 geographical miles, and the gradient would have been described as a gradient of 0·5.

If it is required to find the gradient existing between any two places. The difference in height of the barometric pressure at the two stations multiplied by 15 and divided by the distance in geographical miles gives the difference per horizontal unit, and this is then expressed in integers or fractions of the vertical unit ·01″ of pressure.

Thus in the case quoted—

$$\frac{\cdot 05 \times 15}{75} = \cdot 01'' \text{ which } = \text{a gradient of } 1.$$

The reason why the wind flows in from the S.E. instead of directly in from the N.E. as one would expect, is this:— Air flows in from a denser to a less dense portion of the atmosphere, and the rotation of the earth accounts for the flowing in of the air in a direction which is inclined to the direction of the isobars instead of at right angles to them.

Since the earth is constantly rotating on its axis from west to east. it follows that a body moving in a straight line in the northern hemisphere appears to be deflected to the right, and in the southern hemisphere to the left, this is accounted for by the fact that as a body approaches the equator it is constantly reaching a part of the earth moving faster than the place from whence it came, therefore in the case of a body moving directly towards the equator any lateral movement it received from the rotation of the earth at the place further from the equator would be insufficient to cause it to remain on the same meridian, and therefore it lags behind; conversely a body moving from the equator to either pole is constantly reaching a place where the velocity of the earth is less than it was at the place the body has left, hence the apparent deflection to the right or the left according to whether it is travelling in the Northern or Southern hemisphere. Since the earth rotates on its axis once in 24 hours and the earth at the equator has a circumference of 24,900 miles, it follows that the speed at which any point on the equator rotates is 24,900 ÷ 24 miles per hour, which = 1037·5 miles per hour, whereas in latitude 60° a body has only about half the distance to travel and at the poles it would be 0.

The result of this rotation of the earth is that air flowing into an area of low pressure in the Northern hemisphere is constantly deflected to the right, and therefore air circulates round an area of low pressure in a direction opposite to that in which the hands of a clock travel, and out of an area of high pressure in the same direction as the hands of a clock, whilst in the Southern hemisphere it will (being deflected always to the left) flow into an area of low pressure in the same direction as the hands of a clock travel, and out of an area of high pressure in a direction opposite to that in which the hands of a clock travel.* Buys Ballot, of Utrecht, enunciated the result of these observations in the following law, viz., "Stand with your back to the wind, and the area of the lowest pressure will always be on your left in the northern hemisphere and on your right in the southern hemisphere.

The velocity of the wind in relation to the pressure it is capable of exerting has been expressed by Colonel Sir H. James, R.E., F.R.S., as follows: $V^2 \times {\cdot}005 = P$.

Where V = velocity in miles per hour,
,, P = pressure in pounds per square foot.

Wind is measured by means of instruments called anemometers, some of which indicate the velocity of the wind from which the pressure exerted can be estimated by means of Colonel Sir H. James' formula given above, others indicate the pressure of the wind directly.

It is recorded that Sir Isaac Newton as a boy attempted to estimate the force of a gale of wind which occurred on 3rd September, 1658, by jumping, first, in the direction from, and next, in the direction towards which the wind was blowing.

One of the earliest wind gauges consisted of a swinging rectangular plate, similar to the old signs which at one time swung on hinges from a horizontal bar in front of shops and inns, of late years in front of inns only. The angle which the swinging plate made, with the horizontal bar supporting it, indicating the force of the wind. An instrument of this kind, but fitted with a vane so that the plate is always broadside on to the wind is still employed in Russia (Wild's), which exposes an area of about 72 square inches (15 × 30 centimeters) and weighs about 6·8 ounces.

With Wild's gauge the wind can be fairly accurately measured up to force 8 Beaufort scale, which equals a velocity of about 48 miles per hour, *i.e.*, a fresh gale.

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* Air flows into an area of low pressure in a direction which is inclined to that of the isobars at an angle of about 20 degrees.

With a gentle breeze, having a velocity of 18 miles per hour, the angle of displacement from the vertical is about 45,° and with a velocity of from 44 to 45 miles per hour it is about 80.°

Lind's anemometer which appeared in 1775, consisted of a U shaped tube, one arm of which was bent over at right angles, and the whole apparatus balanced and fixed to a spindle in such a way that by means of a vane attached to it the horizontal arm always directly faced the wind. The U tube contained fluid, and the height to which the fluid was driven up the closed vertical arm of the apparatus was a measure of the velocity of the wind.

Dine's portable pressure anemometer resembles Lind's instrument in that it consists of a U shaped tube containing fluid, and one arm is bent at right angles to the ascending part of the limb, but differs in the following respects, the other limb of the U tube is open, and the instrument is held in the hand and pointed to the wind when required for use, instead of revolving round on a spindle. Also the whole isntrument is enclosed in a metallic case, from which the horizontal limb projects as a metal arm, and before use the instrument is drawn out like a telescope and fixed when fully drawn out by means of a bayonet-joint. In order to avoid the error which arises from the wind moving in a direction not horizontal and, therefore, not tangential to the open vertical arm of the apparatus, this end is enclosed in a metallic cylinder pierced by a ring of holes. On page 170, vol. xviii., of the quarterly journal of R. Met. Soc., Dine, when describing the head of a tube anemometer which he has designed and employed extensively in his researches on wind velocity says, that the vacuum produced by the wind blowing over the mouth of an open tube has been shown to be dependent on the exact perpendicularity of the tube, but if the open-mouth of the tube be enclosed in a cylinder, closed at the top, and having a ring of holes around it, a partial vacuum is formed when the wind passes over the holes which is not subject to the objection referred to in regard to the mouth of an open tube.

The variety of anemometer most commonly employed is Robinson's, this consists of four hemispherical cups, each 1·12 feet apart, and each having a diameter of three inches.

The cups are connected by rods which cross at right angles, and each pair is so arranged that one looks in one direction and the other in the direction opposite, the result is that when any one cup reaches any given point it always presents the same aspect to it, so it comes about that the concave side of one of each pair of cups is always more or less facing or going with the wind, and the convex sides of the other two will be approaching or going against the wind, and since, by reason of their shape, there is greater pressure on the concave than on the convex side, the cups revolve, and always in one direction, from left to right.

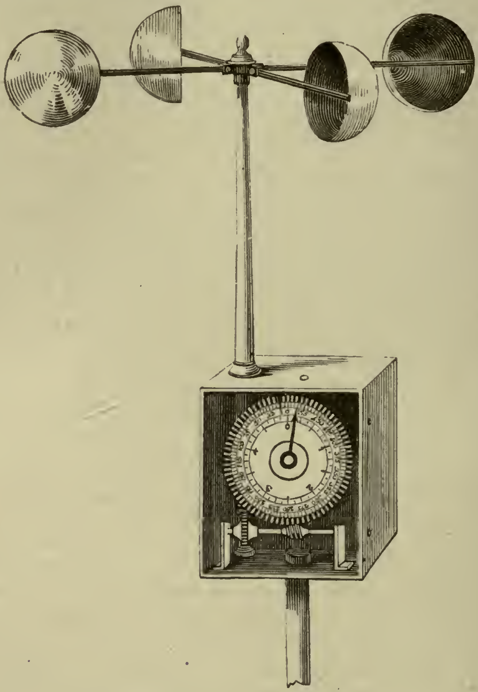

Fig 69—Robinson's Anemometer.

Since each pair of cups is 1·12 feet apart, the circle described by them will be $\frac{22}{7} \times 1'{\cdot}12$, which $= \frac{24{\cdot}64}{7}$ or 3·52 feet.

Dr. Robinson, who designed this instrument, assumed that the cups revolve with $\frac{1}{3}$ the velocity of the wind. Numerous experiments have shown that this factor is too great, as it revolves with a velocity nearer to that of the wind, so that really it should be between 2 and 2·27. Dines says that "probably for a steady wind the higher value is best, but for a gusty wind the lower value, *viz.*: 2·00 is correct."*

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* Dine's Anemometer Comparisons, p. 183, Vol. XVIII., 1892, Q. Journal of R. Met. Soc.

Employing the original factor one complete revolution indicates $3.52 \times 3 = 10.56$ feet of air movement, which means that five hundred revolutions indicate one mile ($500 \times 10.56 = 5280$ feet = 1760 yards).

The mechanism is as follows:—On the shaft supporting the cross-bars bearing the cups is an endless screw, which works into cog-wheels geared so that the instrument is made to show the number of miles travelled by the wind, and if the observation be reduced to a specified time the velocity of the wind in miles per minute, hour, or other period of time can be determined, the wheels cause a dial and pointer to revolve, and on the dial are two circles, the outer showing miles and tenths of a mile up to five miles, and the inner showing spaces for five miles, one complete revolution of the dial moves the pointer through one space on the centre or inner circle, and this inner circle is graduated up to 500 miles. When 500 miles have been travelled the pointer, if it was originally at 0, will have travelled through 100 spaces, and after it has travelled another five will once more be at 0. After our observations have been made, at the end of 24 hours it is usual to set the pointer at 0, but in some instruments the pointer cannot be so set, and the reading has to be noted and the next observation made by deducting the previous observation from it, as in reading a gas-meter. It is most important that Robinson's anemometer be kept clean, well-oiled, and placed in an exposed position at least 20 feet from the ground.*

Wind never blows continuously, and it is most unevenly distributed. This is very noticeable if observations are taken with a pressure anemometer; even when the wind appears to be blowing most steadily, an anemometer shows that it comes in gusts, and the pressure and velocity never remain uniform for more than a few seconds. The destruction wrought by a storm is most irregular, great damage is often done to certain buildings in a street, whereas others escape without the loss of a tile, yet these same houses are apparently equally well-built and equally exposed. Examples of damage done by storms in this irregular manner must be familiar to all.

The force of the wind is recorded in ships' logs and in meteorological reports according to the Beaufort Notation, which was drawn up by Captain, afterwards Admiral Sir Frederick Beaufort, when in command of H.M.S. *Woolwich,* in 1805, viz:—

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* In placing anemometers or taking observations on the force and direction of the wind, the instruments must be placed in exposed positions where no errors can be caused by deflection of the wind by trees or buildings.

BEAUFORT NOTATION TO INDICATE THE FORCE OF THE WIND.

Force.	*Beaufort Scale in words.*			*Mean velocity in miles per hour*	*Mean pressure in lbs. on the sq. foot.*
0	Calm			3	
1	Light air	Just sufficient to give steerage way		8	5·0 oz.
2	Light breeze	With which a well conditioned man-of-war under all sail and clean-full, would go in smooth water	1-2 knots	13	13·5 ,,
3	Gentle ,,		3-4 ,,	18	1·6 lbs.
4	Moderate ,,		4-5 ,,	23	2·65 ,,
5	Fresh ,,	In which the same ship could just carry close-hauled Royals, etc.		28	4·0 ,,
6	Strong ,,	Single reef top-gallant sails		34	5·75 ,,
7	Moderate gale	Double reef jib, etc. ..		40	8·0 ,,
8	Fresh ,,	Triple reef courses, etc. ..		48	11·5 ,,
9	Strong ,,	Close reef and courses ..		56	15·7 ,,
10	Whole gale	With which she could only bear close reefed main top-sail and reefed fore-sail ..		65	21·2 ,,
11	Storm	With which she could be reduced to storm staysails ..		75	28·2 ,,
12	Hurricane	To which she could show no canvas		80-100	31·49 to 49·2 ,,

The direction of the wind is determined by a vane. This may consist of a cone of bunting attached to a grummet and connected by four strings to a stick, or it may consist of an arrow with the tail spread out, revolving round a vertical axis, friction being reduced to a minimum by keeping it clean and well oiled. Waldo, in his *Modern Meteorology,* page 101, says, the first weather-cock on a church spire was set up in the year 820 on a church in the Tyrol, and that the regular observation of wind vanes for meteorological purposes was not begun till 1650 in Italy, and until a few years later in England.

The direction is recorded according to the points of the compass, and its direction described as from a certain quarter, not as in the case of ocean currents, where the direction towards which they flow gives the name.

The points of the compass may with advantage be given. It is not usually necessary to describe wind direction more accurately than to the half-cardinal, or possibly to the false points. The cardinal points are four in number, N, E, S, and W. The half-cardinal are between these, and we have NE, SE, SW, and NW, being four in number. The false points or three letter points are midway between the cardinal and half-cardinal, and consist of NNE, ENE, ESE, SSE, SSW, WSW, WNW, and NNW, eight in number. Whilst between the half-cardinal and false, and between false and cardinal come the by-points, thus: N by E, NE by N, NE by E, E by N, etc., sixteen in number. Four cardinal, four half-cardinal, eight false points, and sixteen by-points. The total 32 being the number of points into which the compass is divided, and since the entire circle comprises 360 degrees, it follows that each point is distant from the next 11° 15′, or in other words, the difference of a point in taking a bearing of an object amounts to 11° 15 .

The knowledge of some of the ways of finding the north in the absence of a mariner's compass, might be useful at some time to one, whether for determining the direction of the wind, or possibly for shaping his own course in some particular direction, so we will mention briefly a few ways. A vertical pole erected anywhere throws a shadow which decreases in size from sunrise to noon, and lengthens from noon to sunset: if we know the true local time, we can always find the points of the compass by observing the shadow; thus at noon, *local* time, in the northern hemisphere the shadow will be shortest and fall towards the N., at 9 a.m. it will fall N.W., at 3 p.m. it will fall N.E. In the southern hemisphere, since the sun is north, at noon the shadow will fall S., at 9 a.m. S.W., at 3 p.m. S.E. Local time, since the introduction of railways, has been lost sight of, but local time is that which is shown by a properly corrected and properly set sun-dial. Since the earth rotates once in 24 hours, it follows that it must always be noon somewhere; in other words, the sun appears on every meridian in succession. (Meridian being the term applied to an imaginary line running north and south drawn through any place, because the sun crosses this line at mid-day. Lat. meridies=mid-day). The circumference of the world being divided into 360 degrees, the rate of angular rotation is therefore 360 degrees for 24 hours, *i.e.*, $\frac{360}{24} = \frac{15}{1}$ which means that for every 15° going west noon will be one hour later, that is to say 15° per 60 minutes, which = 1° per four minutes, so that at any place 1° west of a given meridian, local time will be four minutes later at that place than at the meridian in question. Going round the world then in a westerly direction in 100 days, the traveller would only see 99 noons, because each day would be one per cent. or 14 minutes 24 seconds longer than a day at home. In order, therefore, to prevent confusion in dates when the 180° meridian is crossed, the calendar is put on two days, *i.e.,* one day is missed; and in going round the world in an easterly direction, he would see 101 noons, each day being one per cent. shorter than a day at home, and he would have 101 days doings to record: so that in crossing the 180° meridian, the calendar would have to be put back by showing two successive days as the same date.

If one has a watch showing correct local time, one can always find the north or south by the following simple rule:—In the northern hemisphere, if we point the hour hand to the sun, the spot midway between that point indicated by the hour hand and twelve o'clock (going forwards on the watch before noon, and backwards after noon) will point due south. Take the case of the equinoxes as giving the most obvious proof; we know that the sun rises in the east at 6 a.m. on these occasions, and that if we point the hour hand to the sun, midway between 6 a.m. and 12 will be 9; a line drawn through 9 will then indicate the direction of south. Again, take the case of the sunset at the equinoxes; we know the sun sets in the west at 6 p.m., so if we point the hour hand to the sun and follow the rule given above, 3 o'clock will indicate south. In the southern hemisphere, of course, these directions show us north.

We have given details as to determining the direction and force of the wind, we next have to consider the effect of prevailing winds on health. Many places which otherwise would be well nigh unendurable, become not only habitable, but perfectly healthy, owing to the beneficent action of the Trade winds, which are permanent winds blowing between the tropical and the equatorial calms. At the tropical calms there is an area of high pressure and at the equator an area of low pressure arising from the heating and consequent expansion of the air, which, as a result of expansion, rises in the upper regions of the atmosphere over the tropics, and causes areas of high pressure and calms at the tropics of Capricorn and Cancer.

In the northern hemisphere the "Trades" being deflected to the right as already explained, appear as N.E. winds; in the southern hemisphere they appear as S.E. winds being deflected to the left. These winds follow the sun; as the sun goes north, the S.E. trades are taken across the equator and appear as the S.W. monsoon, which is a hot moisture-laden wind ready to part with its moisture if exposed to cooling influences; conversely, when the sun goes south the Trade winds follow it. The N.E. Trade crossing the equator appears as the N.W. monsoon in regions south of the line, and like the S.W. monsoon is a hot moisture-laden wind.

Monsoons in various parts of the world are produced on a large scale, extending over longer or shorter periods, exactly as land and sea breezes are produced; they are due to heating and consequent expansion, alternating with cooling and consequent contraction of the air over the land, and it is the areas of low pressure formed under these conditions on a vast scale which produce in many parts of the world periodic winds called monsoons. The larger the continent the greater will be the monsoon action, and if, in addition, there are lofty mountain ranges to form, as it were, a shaft which conducts the heated air in an upward direction, then it will be very marked, as in India. The word monsoon is derived from an Arabic word *mansim*, a set time or season of the year, and it is because these winds appear at certain definite seasons that they are known as monsoons. Many people attach considerable importance to winds being set in motion not by the diminished pressure exercising an extractive action, so much as the increased pressure, causing the air to flow into areas of low pressure. A sea-breeze commences first by air pressure being greater over the sea than over the land, and, conversely, a land breeze commences by the colder and denser air over the land flowing out to equalise the pressure where pressure is less over the sea.

Föhns are peculiarly oppressive hot blasts which are felt in different parts of the world. The cause of the Föhn is this, wind is forced to ascend a mountain range, on the weather-side where it is a cold moisture-laden wind, but when it has been deprived of its moisture and warmed by the latent heat given out in the act of condensation, it appears on the lee-side as a hot dry wind; a good example of such a wind is the nor'-wester in New Zealand, which is so unpleasant to the dwellers on the Canterbury plains to leeward of the New Zealand Alps.

Winds exercise very great influence on health, the evil effects of the cold British east wind are due to its peculiar chilling power, which is partly owing to its being dry and so favouring evaporation and causing a reduction of temperature, and partly also because it is cold through having passed over the large tracts of ice and snow on the Continent of Europe.

Variations in Atmospheric Pressure.

We have already alluded to isobars as lines connecting places where the barometric pressure is equal, and we have also spoken of barometric gradients, and how the force of the wind is dependent on the steepness of these gradients. We now have to speak of Variations in Atmospheric Pressure. These are divided into Regular and Irregular.

Regular are divided into Diurnal and Annual.

Irregular into Cyclones and Anti-cyclones.

The Diurnal is seen best in the Tropics, and to a very slight extent in temperate climates. Every day two atmospheric waves pass over the earth, when the crests of these waves are over a place we have the maximum pressures, and when the troughs, we have the minimum pressures ; the two maxima occur about 10 a.m. and 10 p.m., the two minima about 3 p.m. and 3 a.m. These variations in pressure are most noticeable in the tropics, because there, temperature (the prime cause) is high, and also because there, the variations are less likely to be masked by the irregular variations described later on. The first maximum is thought to be due to a gradually increasing temperature which, up to this hour, has caused the air to expand but as yet to an insufficient extent to enable it to overflow in the upper regions of the atmosphere. The second maximum is due to increased density of the atmosphere, the result of the cooling of the air ; the first minimum at 3 p.m. or 4 p.m., is due to the air about that time being at its minimum density, owing to the effects of heat which have caused the air to expand and flow away to the east, from the hemisphere exposed to the sun ; the morning minimum at 3 a.m. is not so marked as the afternoon one, and is thought to be due to the cooling of dust particles and condensation on them of the aqueous

Fig. 70—Some Arrangements of Isobars (*after Abercromby*).

vapour up till now present in the air; the removal of aqueous vapour causes a diminution of pressure, and at the same time the air is warmed by the latent heat set free during condensation.

The Annual variations are readily explained, where the air is hottest the pressure will be least, consequently, we have high barometric pressure over land in winter, and low over the sea in that period, and *vice versa* in summer.

The irregular variations are Cyclones and Anti-cyclones. Cyclones are moving areas of low pressure moving generally from a westerly to an easterly direction, with varying rapidity. In cyclones, the lowest pressure is in the centre, and isobars when plotted on a chart assume, as a rule, a more or less circular form, hence their name. The isobars are generally close together, *i.e.,* the gradients are steep, and the winds circulate round an area of low pressure in accordance with Buy's Ballots Law, *i.e.,* in a direction against the hands of a watch in the northern hemisphere, but in the same direction as the hands of a watch in the southern hemisphere, so that if a ship under sail enters an area of low pressure, and the barometer is observed to be falling, it is evident that the ship is on that tack which will take it into the centre or vortex of the disturbance; on drawing a rough diagram, illustrating this

Fig. 71. Cyclone Prognostics *(after Abercromby).*[*]

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[*] *Popular Weather Prognostics*, by the late Hon. Ralph Abercromby, F.M.S., and William Marriott.

circulation of the wind, it is seen that if the sailing ship proceeds on the port tack it will, in the northern hemisphere, get *into* the dangerous zone, but *out* of it if sailing in the southern hemisphere; whilst if the ship be on the starboard tack in the northern hemisphere it will sail *out of* the area of low pressure, but the same tack in the southern hemisphere will take it *into* the area of low pressure.

When a cyclone is approaching, the barometer is seen to fall, and the temperature to rise, the wind increases, and the sky becomes cloudy, finally rain comes, followed by a clearing sky; the rain ceases, the wind changes, and the barometer once more commences to rise, unless another area of low pressure succeeds it, as is often the case. When a cyclone passes away, if the observer is situated on the south side of the centre of low pressure, as soon as the centre is passed the wind veers or changes with the sun, but if we are to the north of the centre it backs or goes against the sun; backing of the wind indicates, as a rule, further continuance of the storm, whilst veering indicates an abatement, simply because these disturbances, as a rule, pass to the north of us. Thus, a cyclone

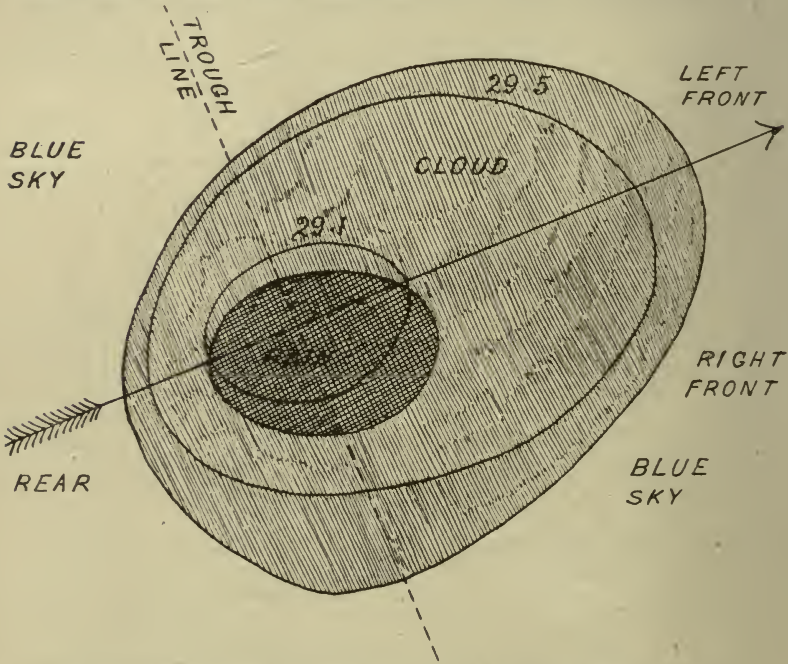

Fig 72—Weather in a Cyclone, Nov. 14th, 1875 (*after Abercromby*). *

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* *Popular Weather Prognostics*, by the late Hon. Ralph Abercromby, F.M.S., and William Marriott.

passing to the N. of a place first brings to that place a south wind, then S.W., W., N.W., N.: whilst if it passes to the S. of a place, it brings first a S., then S.E., E., N.E., and N. wind. The speed at which cyclones travel is generally about 20 or 30 miles per hour in England and the west of Europe, but in America, where the cyclones are more pronounced, the speed is greater. The difference between a cyclone which unroofs houses, wrecks ships, and one which brings merely changes of weather, is one of degree rather than of kind.

Secondary cyclones are, as it were, subsidiary areas of low pressure springing out from the parents, in them the isobars are looped and not completely concentric. V-shaped depressions are areas of low pressure thrust in between areas of high pressure.

Anti-cyclones are irregular areas of high pressure in which the isobars are far apart, or in other words, the gradients are very gentle; anti-cyclones are almost stationary, and sometimes these conditions of pressure remain over a

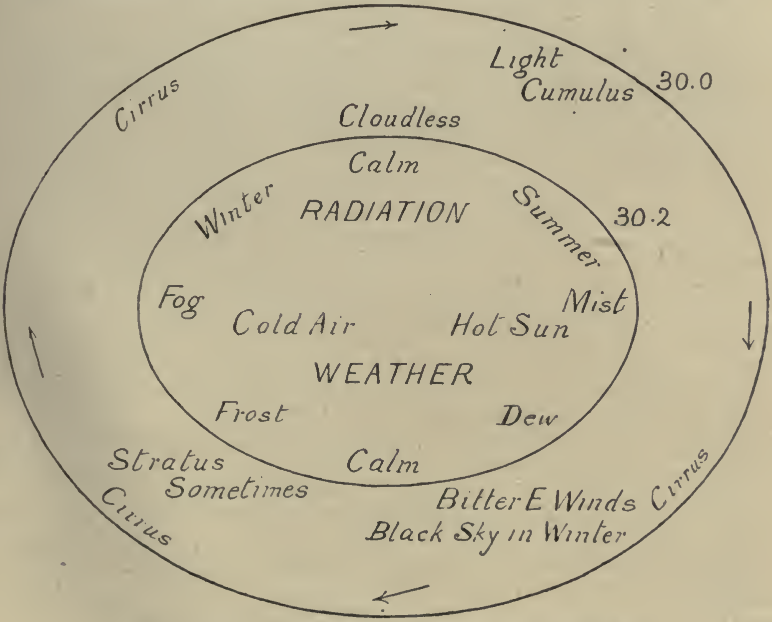

Fig 73—ANTI-CYCLONE PROGNOSTICS (*after Abercromby*) *

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* *Popular Weather Prognostics*, by the late Hon. Ralph Abercromby, F.M.S., and William Marriott.

place for weeks, bringing with them fine weather and light winds. It is evident that the winds in an anti-cyclone must be light, since the gradients are slight, and also that the air must be more or less free from moisture, since the barometer readings are high; high readings not being compatible with much aqueous vapour, since as we have already shown elsewhere that moist air, that is to say, air containing much aqueous vapour is specifically lighter than dry air at the same temperature. In an anti-cyclone, then, we expect to find, and do find, fine weather, in which radiation both from the earth into space and from the sun to earth takes place freely. In summer this means hot weather, and in winter, when the sun is low and its rays strike the earth obliquely it means cold weather. Just as from cyclones we have secondary and V-shaped depressions, so from anti-cyclones we have *wedges*. A wedge is a condition in which a three sided moving area of high pressure is thrust up between areas of low or comparatively low pressure. A *Col* is an area of comparatively low pressure connecting two areas of high pressure, and has been compared to the passes between mountain ranges.

Straight isobars are occasionally seen in a meteorological chart running parallel for great distances, they are generally seen as fore-runners of cyclonic disturbances, and thunderstorms are apt to occur in their vicinity.

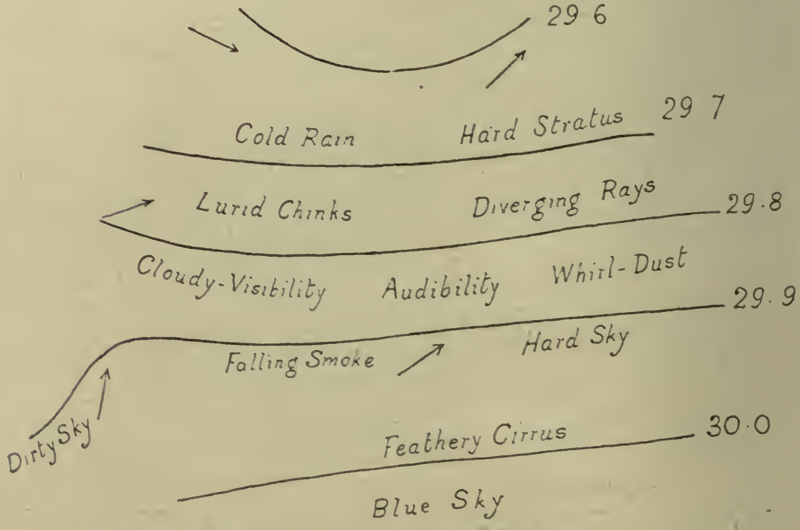

Fig 74—STRAIGHT ISOBAR PROGNOSTICS.

CHAPTER VI.

ATMOSPHERIC ELECTRICITY.

The air is always more or less charged with free electricity, and is usually positively electrified except within a few feet of the earth; sudden changes of state of aqueous vapour, and more especially extensive and rapid evaporation produce changes in the electrical condition of the atmosphere. Under a cloudy sky the air may be positively or negatively electrified, but the earth is always negatively electrified

If from some cause or another a cloud, or clouds, overshadowing the earth become highly electrified with different signs, or with signs different to the earth, if they are sufficiently electrified a disruptive discharge will occur either between the clouds if they are oppositely electrified, or between the clouds and the earth, this discharge, which is *lightning* is intensely luminous, and this is due to the particles in the air traversed by the flash being heated to incandescence. If the discharge takes place through a tree, the tree will split, the cleavage being due to the sudden heating of the sap, the moisture of which is suddenly converted into steam. If the discharge takes place through a moderately good, but yet insufficiently good conductor, such as a chimney stack, the intense vibration caused by the resistance of the particles will cause it to fall, or possibly any moisture contained within its interstices will be converted into steam, and the chimney stack or building will be shattered. The sudden and intense heating of the air through which the spark passes will cause it to expand suddenly, and this contracting again with equal rapidity produces thunder; the sound is caused by the setting in motion of air-waves which, echoing from cloud to cloud, and reaching the earth from different portions of the flash at perceptibly different intervals of time, produces the roar resembling a volley of musketry, or the booming of cannon. Sound travels slowly, viz., at the rate of 1,100 feet a second,* whereas light travels at about 186,000 per second, the

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*This is the rate when the temperature of the air is 32 degrees F., every increase of 1 degree F. in temperature accelerates the rate by 2 ft. a second.

flash is therefore seen before the thunder is heard, the interval depending on the distance, thus if the sound is heard, say, five seconds after the flash is seen, the flash has occurred about 5,500 feet off, or rather more than a mile away.

Thunderstorms occurring more than fifteen miles away cannot be heard, but the flash is visible in the sky.

One of the dangers in a thunderstorm is that known as *return shock* which may be attended with fatal consequences. This is an inductive phenomenon caused by an overhanging highly electrified cloud; as soon as the discharge has taken place between the cloud causing the induction and another cloud, or with the earth, the electricity induced in the body returns to earth. Return shock is by no means always fatal, and the disturbance which many nervous people feel during a thunderstorm may, in many instances, be attributable to mild shocks of this kind.

When telephone gongs ring during thunderstorms, it is the return shock which is the cause. Lightning conductors are metal rods attached to the highest points of buildings or to the masts of ships; to be efficient they must be made of sufficient size and good conducting metal such as iron or copper, and this must lead into moist earth or the sea. A lightning conductor depends for its action on induction or the power possessed by pointed objects to carry off from the body to which they are connected the opposite kind of electricity to that possessed by the body causing the induction, in other words it tends to equalise or reduce to a minimum differences of potential between the clouds and the earth.

Thus, if a positively electrified cloud be hanging over the earth in a situation where there is a conductor, negative electricity is attracted to the point, and its tension being sufficient to overcome the resistence of the air it flows off to the cloud neutralising or tending to neutralise it. A lightning conductor protects a conical space, the radius of the base of which is about double its height.

St. Elmo's Fire is a luminous electrical discharge, occasionally seen at the yard-arms or mast-heads of ships, it is simply due to induction; air positively electrified, inducing negative electricity to pass off and combine with a brush-like series of sparks from pointed extremities such as we mentioned.

Aurora is an electrical phenomenon caused by electrical discharge occurring at great altitudes in rarefied air free from moisture, it is known as Aurora Borealis in the Northern, and

Aurora Australis in the Southern hemisphere, and is seen only in high or moderately high latitudes; the positive electricity in the upper region of the air is thought in these cases to be due to the effects of the sun causing evaporation from the sea, and overflow of air at great altitudes in the tropics, the overflow differently electrified, eventually arriving at the polar regions. The appearance of the Aurora or Northern Lights is familiar to many, but in Europe it is chiefly those who dwell or have visited places between latitude 66° and 75° who have seen it at its best, the appearance is that of an arch or crown of light, from which bright streamers of fire shoot upwards with a pulsating movement, the arch appears to be very high up, and is situated over the magnetic pole.

CHAPTER VII.

CLIMATE.

Climate is a word used to denote the prevailing conditions of the atmosphere over a portion of the globe as regards temperature and relative humidity. The factors which take part in the formation of any particular climate are often very numerous, and these will be considered in turn. The word climate is derived from the Greek word *κλίμα* (a slope), because it was thought at one time that the angle at which the sun's rays strike the earth in different latitudes was in itself sufficient to account for all the various climates. Latitude, as we shall see, is undoubtedly the most important factor, but its influence may be considerably masked by other circumstances. Dr. Henry Bennett * divides climates into five groups:

(1). *Warm Climates*, which include the equatorial, tropical, and sub-tropical regions, where there is (as a rule) heavy rainfall, high temperature and dry and rainy seasons.

(2). *Temperate Climates*, showing a wide annual range of temperature, rainfall chiefly in autumn and winter, and a mean temperature of between 50 and 60 degrees F.

(3). *Cold Climates*, with long winters, short summers, and "rainfall," chiefly in the form of snow.

(4). *Marine Climates*, characterised by an absence of extremes of temperature, rainfall abundant and fairly evenly distributed throughout the year.

(5). *Mountain Climates*, in which the chief features are: Low barometric pressure, extremes of temperature, excessive solar and terrestrial radiation, as a result of increased diathermancy of the air caused by the small amount of dust particles and aqueous vapour present.

To these we might add another type, viz.: *Continental*, which consists in extremes of heat and cold prevailing over large inland tracts of country, according to whether it is summer or winter.

The factors in the production of climate are: (1) Latitude; (2) Altitude; (3) Configuration of the land; (4) Proximity

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* Quoted by Dr. C. Theodore Williams in *Treatise on Hygiene*, Vol. I., p. 203.

of the sea; (5) Position in regard to high hills or mountain ranges; (6) Prevailing winds; (7) Rainfall; (8) Vegetation; (9) Soil.

If we now consider these in turn we can judge of their relative importance.

(1). Latitude: It is evident that the more vertical the direction of the sun's rays the greater will be their heating power, because a beam of light falling perpendicularly on to a surface strikes a smaller area than when it falls obliquely;* in addition it travels through a shorter distance, and since the lower strata of the atmosphere contain a large amount of heat absorbing materials it follows that the shorter the distance which the sun's rays travel through these heat absorbing strata the less will be the loss. The Sun in his apparent journeyings appears vertically over every portion of the Torrid Zone twice in the year, but outside this zone the sun is never vertical, at the Summer Solstice (21st June) the meridian altitude of the sun at places in the Northern hemisphere is equal to the complement of the latitude plus 23° 27′ 44″ (by complement of the latitude is meant 90° minus the latitude), whilst in the Southern hemisphere on 21st June the meridian altitude at any place is equal to the complement of the latitude minus 23° 27′ 44″; at the Winter Solstice (21st December) the above conditions are reversed. At the Equinoxes (21st March and 23rd September) day and night are equal all over the world, and the intensity of solar radiation is inversely proportional to the latitude, the higher the latitude the less the amount of solar radiation received. A consideration of the above facts will readily explain the important part that latitude plays in the formation of climate.

(2). Altitude: The importance of altitude in the production of a climate is shown by the fact that as one ascends lofty mountains in tropical countries the climate varies as we ascend, which materially affects the nature of the vegetation, so that a mountain sufficiently lofty, in the equatorial region, to have a portion of it covered by perpetual snow, would show zones of vegetation at various heights, corresponding with that experienced in every latitude from the equator to the poles; the snow line (corresponding with the arctic regions) at the equator is above 16,300 feet. The reason for

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* To prove this, take an ordinary sheet of ruled paper and draw two sets of parallel lines of equal breadth between two of the ruled lines, one set being drawn perpendicular and the other at an angle to the ruled lines, now compare the breadth of the areas covered; expressed mathematically, the area which a beam of sunlight will cover is in inverse proportion to the sine of the obliquity.

the fall in temperature with altitude is, that air is more or less diathermanous according to whether it contains little or much aqueous vapour and dust particles, consequently it is scarcely heated at all by the passage of the sun's rays through it in the higher regions of the atmosphere, and is only warmed by the obstructions to the sun's rays just mentioned and contact with the warm earth where it becomes warmed by convection; the higher we ascend the less is the pressure to which the air is subjected and consequently it expands more and more as the pressure diminishes, but by this expansion work is done against gravity and therefore heat is consumed. If the air were dry then the fall in temperature would amount to 1° F., for every 180 feet of ascent, but as a matter of fact the air is never quite dry, so that the fall of temperature works out to about 1° F. for every 300 feet, the latent heat given out on the condensation of water vapour which occurs as the air is cooled, counterbalancing to a certain extent the amount of heat used up in the work of expansion against the attraction of gravity.

(3). Configuration: The nature of the surface of the land, whether flat or hilly, plays an important part in modifying the climate of a place; places where the slope of the land faces the sun at noon will enjoy a much warmer climate than those in the same latitude, the slope of which looks away from the sun. Hills or mountains may modify the climate by setting up currents; on a level plain under the influence of a strong sun the air will be heated and rise *en masse,* but where there are hills these will act like a chimney, by creating a draught and thereby cause powerful currents to be set up. Again, if a place be situated low down between hills, the air immediately over it will often be colder than at other places higher up on the hillsides, because the colder and denser air flows down the hills and remains like water in a hollow, thus displacing the warmer and lighter air, which is driven upwards.

(4). Proximity of the sea; Continental places near the sea and small or moderate sized islands enjoy a climate which is tempered by the presence of water, which having such high specific heat is slowly warmed and slowly cooled, and so effectually prevents rapid or extensive changes of temperature. Then again the air in places near the sea contains more aqueous vapour than does the air over inland places far removed from large expanses of water, this aqueous vapour then exercises its action as a screen in checking solar and terrestrial radiation; in inland places, where the air is dry or containing little aqueous vapour, the absence of this screen gives rise to extremes of heat and cold, which has already been alluded to when speaking of the "continental" type of climate. Ocean currents flowing along a coast may modify the climate considerably. Both warm and cold currents are met with in various parts of the world; as an example of the former we may mention the Gulf stream, which so markedly softens the climate of the west coast of Europe; as examples of cold currents we may mention the cold Labrador, or Arctic current, and the South Equatorial current. The Arctic current flows out of Davis Strait, over the Newfoundland Bank, and down the east coast of N. America, between it and the Gulf Stream. The difference in temperature between these two currents is considerable, in the early part of the year it may amount to 30°, and from 25° to 15° during the warmer months. It is owing to this cold current that the climate of the east coast of Canada is so cold and damp in winter and so bracing in summer. The other example of a cold current which we mentioned is that known as the Peruvian, or Humboldt current, which from 40°S. runs to the northward along the west coast of S. America as far as the Bay of Panama, where it merges into the South Equatorial current, which flows past the Galapagos Islands, the climate of which it affects most favourably, giving them a cooler climate than other places situated on the equator.

(5). The proximity of Hills or Mountains: When hills or mountains are present of considerable height and perpendicular to the prevailing winds their influence on climate will be very marked; the climates on the weather and lee sides of these hills will be quite different; places on the windward side will have a heavier rainfall than those on the leeward side, because condensation will occur when winds laden with water-vapour reach the hills. Condensation occurs for two reasons: the moisture-bearing winds are cooled to a temperature below the point of saturation by actual contact, and secondly, they are forced to ascend and so suffer further loss of moisture, due to the expansion of the air under diminished pressure, which causes, as we have previously shown, a fall in temperature and condensation of water vapour as a consequence. On the same side of the hills the weather will frequently be cloudy and rainy, whilst on the other side it will be drier and brighter, there will be fewer clouds to obscure the sun, and there will be more radiation—giving colder winters and warmer summers. It would seem hardly necessary to say that the wind which flows over the hills, after being depleted of aqueous vapour, descends and becomes in consequence warmed, the conditions being the converse of those described when speaking of the cooling of air as the altitude increases.

(6). Prevailing winds: The effect of winds on climate is very great; it is not difficult to find examples of places in the same latitude where the climates are quite different, simply because the prevailing winds have been subjected to different conditions before they reach that place; for instance, a wind which has its origin in an overflow from the same area of high pressure into one of low pressure, may have travelled to one place over a sandy desert and to another across a sea, in the one place it will be felt as a drying wind, which in no way interferes with solar or terrestrial radiation, whilst in the other, as a moist wind, it will effectually act as a screen to radiation. If this occurs in low latitudes the disadvantages of a steamy atmosphere can scarcely be over-stated. By studying the map we can explain the cause of the direction of the prevailing winds by noticing the distribution of land and water in the region in question, for we know that areas of low atmospheric pressure are formed over the land in summer, and over the sea in winter, with high pressure over the sea in summer, and over the land in winter, and that air will, as already stated, flow into the low pressure areas from those having higher pressure at an angle of about 20° to the isobars, unless there are some physical conditions, such as a range of mountains in the region under consideration, which will set up currents and so cause a divergence from the course the winds would naturally follow. In selecting places for sanatoria the direction of prevailing winds should influence one more than anything, since it has recently been shown how great an influence prevailing winds have on the mortality rate for phthisis.

(7). Rainfall: Some places, for example, like the west of Ireland, owe their peculiar mildness of climate to the large amount of rain which they receive; warm moisture-laden winds coming over the sea lose much of their vapour when they come in contact with the colder earth and the condensation which brings about this loss sets free a great deal of heat, which to a large extent compensates for the loss due to the interception of sunshine by the clouds which the warm, moist, rain-bringing winds must give rise to. It is more important when considering the climate of a place to know the number of rainy days than the actual rainfall; a place with a heavy rainfall might enjoy a warm, dry climate during the greater part of the year, whereas another place, the rainfall of which was slight, might be cold and damp, and suffer from a want of sunshine, because at that place there were so many rainy days, that is to say, days on which the actual rainfall may have been slight, but which were cloudy and therefore sunless.

(8). Vegetation: The presence or absence of vegetation affects climate considerably; where vegetation is scanty the air will, as a rule, be dry and subject to extremes of temperature, many such places having undergone a complete change of climate after extensive tree-planting. Forests act chiefly in affording a screen to the wind, and in valleys where the hills are covered with trees the downflow of cold air is interfered with and the cold air distributed, so preventing the formation of the cold stratum so often found in valleys where there are no trees. The climate in large forests is more equable than in the open country, although evaporation proceeds extensively from the leaves of trees, yet the shade afforded by them and their mechanical action in checking air movement retards evaporation from the soil and more than counterbalances that from the leaves, so that the air in forests is always humid, and it is also cooler in summer and warmer in winter than out in the open.

(9). Soil: Soils which permit of good natural drainage will tend to make a climate warmer and more agreeable than those retentive of moisture. The air over soils readily drained will be dry, and the soil will .become more readily heated because it is not chilled by the process of evaporation in the way that a moister soil is. The colour of the soil is an important factor; where this is dark it will absorb much more heat than where it is light coloured. Sand is very retentive of heat, but since the air of sandy soils is drier than over heavy soils, where clay is abundant the heat retaining property of sand is to a great extent compensated by the increased diathermancy of the air over it, which allows a greater amount of terrestrial radiation to take place. Soils which from their closeness do not allow the water to sink in, or run off, give rise to a cold climate, this is particularly the case with clayey soils, which become heated very slowly and consequently from the amount of moisture they hold, the air over them is always cold and damp, with the disadvantages attending diminished diathermancy.

APPENDIX *(A)*.

HYGROMETRICAL TABLES (GLAISHER).

I.—TABLE OF FACTORS.

Reading of the Dry-Bulb Thermometer.	*Factor.*	*Reading of the Dry-Bulb Thermometer.*	*Factor.*
20 degrees	8·14	56 degrees	1·94
21 ,,	7·88	57 ,,	1·92
22 ,,	7·60	58 ,,	1·90
23 ,,	7.28	59 ,,	1·89
24 ,,	6·92	60 ,,	1·88
25 ,,	6·53	61 ,,	1·87
26 ,,	6·08	62 ,,	1·86
27 ,,	5·61	63 ,,	1·85
28 ,,	5·12	64 ,,	1·83
29 ,,	4·63	65 ,,	1·82
30 ,,	4·15	66 ,,	1·81
31 ,,	3·70	67 ,,	1·80
32 ,,	3·32	68 ,,	1·79
33 ,,	3·01	69 ,,	1·78
34 ,,	2·77	70 ,,	1·77
35 ,,	2·60	71 ,,	1·76
36 ,,	2·50	72 ,,	1·75
37 ,,	2·42	73 ,,	1·74
38 ,,	2·36	74 ,,	1·73
39 ,,	2·32	75 ,,	1·72
40 ,,	2·29	76 ,,	1·71
41 ,,	2·26	77 ,,	1·70
42 ,,	2·23	78 ,,	1·69
43 ,,	2·20	79 ,,	1·69
44 ,,	2·18	80 ,,	1·68
45 ,,	2·16	81 ,,	1·68
46 ,,	2·14	82 ,,	1·67
47 ,,	2.12	83 ,,	1·67
48 ,,	2·10	84 ,,	1·66
49 ,,	2·08	85 ,,	1·65
50 ,,	2·06	86 ,,	1·65
51 ,,	2·04	87 ,,	1·64
52 ,,	2·02	88 ,,	1·64
53 ,,	2·00	89 ,,	1·63
54 ,,	1·98	90 ,,	1·63
55 ,,	1·96	91 ,,	1·62

TABLE II.—TENSION;

or Elastic Force of Aqueous Vapour in inches of Mercury for every degree of Temperature from 0 to 90.

Temperature.	*Tension.*	*Temperature.*	*Tension.*
0 degree	·044	39 degrees	·238
1 ,,	·046	40 ,,	·247
2 degrees	·048	41 ,,	·257
3 ,,	·050	42 ,,	·267
4 ,,	·052	43 ,,	·277
5 ,,	·054	44 ,,	·288
6 ,,	·057	45 ,,	·299
7 ,,	·060	46 ,,	·311
8 ,,	·062	47 ,,	·323
9 ,,	·065	48 ,,	·335
10 ,,	·068	49 ,,	·348
11 ,,	·071	50 ,,	·361
12 ,,	·074	51 ,,	·374
13 ,,	·078	52 ,,	·388
14 ,,	·082	53 ,,	·403
15 ,,	·086	54 ,,	·418
16 ,,	·090	55 ,,	·433
17 ,,	·094	56 ,,	·449
18 ,,	·098	57 ,,	·465
19 ,,	·103	58 ,,	·482
20 ,,	·108	59 ,,	·500
21 ,,	·113	60 ,,	·518
22 ,,	·118	61 ,,	·537
23 ,,	·123	62 ,,	·556
24 ,,	·129	63 ,,	·576
25 ,,	·135	64 ,,	·596
26 ,,	·141	65 ,,	·617
27 ,,	·147	66 ,,	·639
28 ,,	·153	67 ,,	·661
29 ,,	·160	68 ,,	·684
30 ,,	·167	69 ,,	.708
31 ,,	·174	70 ,,	733
32 ,,	·181	71 ,,	·759
33 ,,	·188	72 ,,	·785
34 ,,	·196	73 ,,	·812
35 ,,	·204	74 ,,	·840
36 ,,	·212	75 ,,	·868
37 ,,	·220	76 ,,	·897
38 ,,	·229	77 ,,	·927

Temperature.		*Tension.*	*Temperature.*		*Tension.*
78 degrees	...	·958	87 degrees	...	1·282
79 ,,	...	·990	88 ,,	...	1·323
80 ,,	...	1·023	89 ,,	...	1·366
81 ,,	...	1·057	90 ,,	...	1·410
82 ,,	...	1·092	91 ,,	...	1·455
83 ,,	...	1·128	92 ,,	...	1·501
84 ,,	...	1·165	93 ,,	...	1·548
85 ,,	...	1·203	94 ,,	...	1·596
86 ,,	...	1·242	95 ,,	...	1·646

APPENDIX (*B*).

CHARACTERISTICS OF CLIMATE MET WITH IN SOME BRITISH POSSESSIONS.

AUSTRALASIA.—SYDNEY, N.S.W.—Latitude 33° 51′ 41″ S. The mean annual temperature is 63° F. During the summer months, December, January and February, the weather is hot and steamy, with a mean temperature at noon of about 80°; hot winds from the N.W., known as Brickfielders—from their peculiar parching dry heat—are experienced from time to time during these months, and are followed, as a rule, by cold winds, called Southerly Busters, which come on very suddenly and bring with them clouds of dust which penetrate everywhere, these winds are very violent, the velocity varying from 40 to 70 miles an hour, and even 90 miles an hour has been recorded. When these winds commence to blow the fall in temperature is very rapid, a drop of 20° being by no means uncommon; their usual termination is a thunderstorm and heavy rain. The annual rainfall which occurs, chiefly between February and June, amounts to about 49 or 50 inches, falling on about 157 days.

MELBOURNE.—Approximate Latitude 38° S., in Victoria, has a mean annual temperature of 58·0° and a climate which is very agreeable; the air is much less humid than in Sydney, and the rainfall averages about 25·85 inches or a little more than half that of Sydney.

ADELAIDE.—Approximate Latitude 35° S. in S. Australia enjoys a dry climate, with a mean annual temperature of 74°. During the summer months the average temperature is 100°, but the thermometer frequently shows a temperature of from 110° to 115°, the heat though somewhat trying is much less oppressive than that of Sydney, even when it may be 10° or 15° higher, because of the lower relative humidity. The winter is, as a rule mild, with an average temperature of 53°, but the temperature has been known to fall to 35° F. The annual rainfall is about 21 inches and received during the winter months between May and October.

PERTH.—Latitude 32° S., in Western Australia, enjoys a mean annual temperature of 65°, with a climate which, owing to the large tracts of sandy soil, is peculiarly dry and healthy; the rainfall received principally in the winter months, June, July, August and September amounts to about 33 inches.

BRISBANE.—Latitude 27° 28′ S., the capital of Queensland, has a climate which is more uniformly hot than that of the other Australian colonies; it is agreeable in the winter months, but though very hot during the summer the heat is less oppressive than in some of the other parts of Australia. The temperature ranges between 106° and 35° and the mean annual temperature is 69°. The rainfall occurs chiefly during the summer months, December, January and February, at which season the air is hot and steamy. In 1893 an exceptionally heavy rainfall occurred during the first week of February, when over 77 inches fell in four days in the Blackall ranges near Brisbane; it was owing to the floods which occurred in consequence of this excessive rainfall that H.M.S. *Paluma*, a gunboat employed in the surveying service, was stranded in the Botanic Gardens at Brisbane.

NEW ZEALAND.—The climate is on the whole temperate, but shows considerable diversity in the various parts of the country. That of Auckland may be described as sub-tropical; Wellington is, from its situation in respect to Cook's Straits, (which divides the North and South Islands), peculiarly liable to boisterous stormy weather. Dunedin, in the South Island, has a climate very similar to that of England, and is very suitable for those who have become run down in health by too long residence in a warm climate, or who have suffered from a malarial fever.

TASMANIA.—HOBART.—Approximate Latitude 43° S., situated on the Derwent river, enjoys a peculiarly genial climate. English fruits grow here in a manner quite unknown in England, and in the case of apples attain a much larger size than at home. The mean annual temperature is is 54·5° F. The mean summer temperature is 62°, and mean winter temperature 49°, and a rainfall of about 20 inches which is well distributed over the year; on an average there are about 145 rainy days.

BARBADOS.—Latitude 13° 7′ 39″ N., has a mean annual temperature of about 76°, with an extreme range of temperature between 91° or 92° and 57° F. The rainfall averages nearly 53 inches and the mean annual relative humidity is about 67 per cent.

BERMUDA.—Latitude 32° 17′ 40″ N., enjoys an equable and temperate climate with a temperature of 70°, the range being as a rule between 85° and 50°. During the winter months (November to April) it is visited by many people from Canada and the United States in order to escape the rigours of the continent during that season. In 1897 the maximum temperature for the year was 87·9° and the minimum 50°, and the mean relative humidity was 79 varying between 70 and 84. The average annual rainfall is about 60 inches evenly distributed throughout the year.

British Guiana.—Capital, Georgetown, has a warm climate with a limited range of temperature (between 89° and 70°), with a mean of about 80°. The hottest period is from September to November. The prevailing winds are from the N.E. and blow during most of the year mitigating considerably the heat. The rainy seasons are between June and August and December and February, with a total rainfall of about 82 inches. Yellow fever at one time prevalent is now only met with occasionally, but there is a good deal of malarial fever on the coast.

Canada.—Esquimalt.—Situated in Vancouver Island, Approximate Latitude 48° 25′ N., enjoys a marine climate with the absence of extremes met with in the interior of Canada. The lowest temperature recorded in two years is, according to Dr. P. H. Bryce,[*] 8° F., the lowest monthly average 20° F., and the highest temperature in summer 82° F. The air is drier than on the coast in England and the rainfall is less, and is received chiefly during the winter. The comparatively small amount of rainfall received at Esquimalt is due to its sheltered position, the moisture-bearing winds having been already partly drained by condensation which occurred on striking the high coast-line.

Nova Scotia.—Halifax.—Approximate Latitude 44·5° N. The temperature ranges between 88° and 11° below zero with a mean annual temperature of 65° F. The average rainfall per annum is 34 inches. The winters which are warmer than those of places in the interior are nevertheless cold and damp, owing to the cold Labrador current, but the climate in the summers, commencing in June, and the autumns, up to November, leaves nothing to be desired.

Quebec.—Montreal and Quebec both possess climates which are healthy and bracing. The mean annual temperature of Montreal, Latitude 45·32° N. is 42·4° with a range of from 91° to 12° below zero. On 9th January, 1859 the phenomenal temperature of −43° F., was recorded. The annual rainfall amounts to about 27 inches.

Cape Colony.—The mean annual temperature at Cape Town (approximate Latitude 34° S.) is 64·5° F.; the mean summer temperature is 71·5° F., whilst that of spring and autumn is 64·5° F., and the winter mean temperature is 57·2° F.[†] In 1891 the absolute maximum temperature was 96·1° F., which occurred in January, and the absolute minimum temperature was 36·6° F., occurring in July. The prevailing

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[*] *The Climates and Health Resorts of Canada.*—By Dr. P. H. Bryce.

[†] Official Handbook of the Cape and South Africa.

wind from November to March is that known as the "South-Easter" or "Cape Doctor," this being a moisture-laden wind from the sea, loses its moisture when forced to ascend Table Mountain, and in so doing forms the apparently permanent cloud known as the "Table Cloth"; at other times the wind is frequently from the N.W. The average rainfall in the Cape peninsula, taken for 50 years, is 25·46 inches falling on from 45 to 80 days. The mean relative humidity in the hot month of January, 1891, was 69 and that in the cold month of July, 67. The mean annual relative humidity is 67. The climate is equable with a clear dry atmosphere, very suitable to those suffering from anæmia, or convalescing from diseases contracted in warm or malarial places, or in fact convalescing from any severe illness.

CEYLON.—The mean annual temperature at Colombo is about 81° F., the temperature varies little throughout the year. The coolest months are December and January, the hottest April and May. The climate is warm but fairly healthy. The rainy seasons are from April to June and September to November; the average annual rainfall is 100 inches.

FALKLAND ISLANDS.—The climate is healthy, the winter temperature ranges between 30° and 50° and that of the summer between 40° and 65°.

FIJI.—Capital, SUVA. The climate is warm but healthy, the temperature ranges from 94° to 60°. The average temperature in the cool season is 72° and in the hot season 84°

GIBRALTAR.—Latitude 36° 6′ 20″ N., has a mean annual temperature of 64·5°; in 1897 the temperature ranged between 36·8° and 94°, with a mean annual minimum of 57·4° F., and a mean annual maximum of 71·6° F. The mean relative humidity varies between 62 per cent. in June and 81 per cent. in November. The mean annual rainfall is 34·5 inches; in 1897 it was 27·63 inches. The climate is hot during the summer months but invigorating and agreeable during the winter and spring up till May. The most trying feature of the summer is an easterly wind, known as the Levante, which is exceedingly hot, damp, and depressing, whilst the wind from the west, known as the Poniente, is cool and refreshing and is not confined to any particular season.

HONG KONG.—Latitude 22° 16′ 52″ N., shows a range of temperature usually between 96° F. and 42° F., but 99° F. has been recorded in September, and 32° F. in February; the mean annual temperature is about 74·5° F.; the relative humidity varies between 70 per cent in November, and 86 per cent. in January and February, the mean annual relative humidity is about 78 per cent. The average annual rainfall is 90·17 inches, which falls chiefly between May and September during the S.W. monsoon; in 1897 over 112 inches of rain fell; in 1860 there was a minimum rainfall of 59·72 inches, and the highest record is 120·66 inches. The climate is very hot and exhausting when the S.W. monsoon is blowing, the temperature varying between 80° and 99°, with a difference of 10° between day and night. When the N.E. monsoon prevails from November to January, the weather is cool and healthy and often bracing; the most trying feature during the winter months is the liability to sudden changes in temperature, at one part of the day the heat may be almost tropical, whilst at another period it will be cold, with a cutting North wind.

JAMAICA.—Situated between 17° 43′ and 18° 32′ N. Latitude. Tbe mean annual temperature at Kingston is 82° F., and varies between 87·8° and 70·7°. The annual rainfall averages 34 inches, and falls chiefly between October and February. The land and sea breeze is peculiarly well marked in Jamaica.

LEEWARD ISLANDS.—Comprising Antigua with Barbuda and Redonda (small island dependencies), St. Christopher and Nevis with Anguilla or Little Snake Island (a dependency), Dominica, Montserrat and the Virgin Islands are all situated between 15° and 19° N. Latitude, enjoy a warm climate, which is for the most part dry; the mean annual temperature is about 80°. The hottest weather is experienced between May and October, and the rainy season is from June to November. The island of Dominica has the greatest rainfall in the group, with an average rainfall of 120 inches. The climate in the lowlands is very humid, owing to the large amount of vegetation. In August, September and October the Trade Wind becomes weak, and it is during this period that hurricanes occasionally occur.

MALTA.—Latitude 35° 53′ 49″ N. has a mean yearly temperature of from 53° to 66·2° F., with a mean maximum of about 70° and mean minimum of 62·1. The summer months from the middle of June to the early part of September are hot, the temperature ranging between 71° and 87° F. In 1897 the maximum temperature was 94·6° F. on 14th September, and the minimum was 47·2° F. on 31st January. In winter the temperature varies as a rule between 48° and 58°, but occasionally rises above or falls below these limits. The average rainfall in 1897 amounted to 13·26 inches, in 1899 it was 17·8 inches; the mean annual relative humidity is about 72. The prevailing winds in summer are easterly, with occasional Siroccos (S.E. winds) which are hot damp winds exceedingly oppressive and relaxing. Violent gales from the N.E. are met with from time to time between November and April, they are known locally as Gregales.

NATAL.—The mean annual temperature at Durban is 70° F.; the climate on the coast of Natal is (except during the winter months) tropical and ennervating. The highest temperature at Durban according to Dr. C. Lawrence Herman,* was 99° F. in 1875, and the lowest 45° F., with a mean daily range of 17·05. The approximate mean daily temperatures were highest, 82° F., lowest, 56° F., and the total rainfall was 54·78 inches falling on 131 days. The rainy season is from October to March inclusive, and the prevailing winds are alternately from N.E. to E. and from S.W. to S.

NEWFOUNDLAND.—The climate is healthy and bracing; the temperature rarely falls below 0° F. in winter, and ranges in summer between 70° and 80° F. Off the banks of Newfoundland fogs are apt to occur at all seasons for reasons already given on page 247, but they are especially common in June and July. When the fogs occur with easterly winds they extend to a much greater height than those which take place during calms.

SIERRA LEONE.—Latitude 8° 29′ 30″ N., possesses a climate which is warm and damp, and is therefore ennervating; malarial fevers are most prevalent at the commencement and termination of the rainy season (May to October). Temperature varies as a rule between 89° and 62°; in 1897 the absolute maximum was 93·6 on 19th January, and the mean maximum was 84·2° F., in the same year the minimum temperature was 66·8° F. on 19th October, and the mean minimum was 74·1° F., with a mean of 79·1° F. The mean annual relative humidity is about 72, it varies between 64 and 86, August being the month when it is highest. The rainfall in 1897 was 164·3 inches. Between December and February (inclusive) a very dry easterly wind laden with fine sand off the desert, called the Harmattan, occasionally blows and may last a day or two or even a fortnight at a time, its direction at Sierra Leone is from E.S.E.

SINGAPORE.—Latitude 1° 16′ N., situated almost on the equator, shows no clearly defined seasons; rain falls throughout the year with 167 as the average number of rainy days and 91·8 inches of rainfall, but the rainfall has, during one year, amounted to as much as 123 inches falling on 209 days, and also reached a minimum total of 58·4 inches falling on 119 days. In 1898 the maximum shade temperature was 89·4° F.

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*Official Handbook of the Cape and South Africa.

in May, and the minimum temperature was 73·1° F. in January, or a total range of 16·3 F. The mean range is 12·7° viz., from 86·8° F. to 74·1° F. In 1898 the greatest range in any month was in March, when the temperature ranged between 88·1° F. and 73·3° F., *i.e.,* through 14·8° F., May coming next with a difference of 14·2° F. between the highest and lowest temperatures, whilst in December the range was least, viz., 10·7° F. The extremes in 17 years are 94° F and 63° F. Relative humidity averages 81 per cent., saturation being 100.

Although Eygpt is not a British possession its climate is so remarkable as to demand a short notice. The climate is a singularly healthy one, and by reason of its dryness is peculiarly suitable as regards Cairo and Upper Egypt for convalescents from acute illness and also for cases of early tuberculosis, and anæmia, whilst those suffering from rheumatic affections benefit much by residence in Egypt on account of the dryness of the air. The mean annual temperature at Cairo in 1890 was 71·51° F., and during the years 1887-90 it was 74° F. The highest mean monthly temperatures were in the year 1890 85·75° F. and 85·55° F. in July and August respectively, whilst the mean temperature during December, January and February were respectively 60·69° F., 53·64° F., and 59·05° F. On the coldest days in Cairo the thermometer never sinks below 34° F., whilst on the hottest days it may occasionally amount to 112° F. Snow is recorded to have fallen at Cairo in 1855, but this was very exceptional. The mean annual temperature at Alexandria is 68·9° F., at Port Said, 71·0° F., at Ismailia, 72·0° F., and at Suez, 72·6° F.

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