HYGIENE

LEWIS'S PRACTICAL SERIES

LOUIS C. PARKES

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HYGIENE AND PUBLIC HEALTH

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BY

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THIS WORK IS, BY PERMISSION,

DEDICATED,

AS A TOKEN OF ESTEEM AND GRATITUDE

BY

THE AUTHOR.

PREFACE.

My experience as a teacher at University College has for some time led me to believe that a small work on Hygiene, concisely yet clearly written, would be of value to those who are desirous of becoming acquainted with this important branch of science.

The sanitary education which is deficient in a knowledge of the sub-divisions of the main science, must be considered in some degree incomplete. It has been my endeavour therefore to occupy, within a small space, nearly the whole field of sanitary science, and to give the reader the opportunity of acquiring such an elementary knowledge on every topic as will enable him to refer with advantage to the larger and more abstruse text-books.

It has also been impressed upon me that the necessity of dealing with figures and statistics, and of making mathematical calculations, which is so inseparably connected with all kinds of public health work, often offers considerable difficulties to medical men, whose opportunities for the display of mathematical knowledge may have been but very limited since leaving school. By means of numerous examples and illustrations, where they seemed desirable, it is hoped that the reader will be enabled to obtain a clear comprehension of these matters.

The chapter on Removal of Excreta is, perhaps, somewhat unduly lengthy in proportion to the size of the whole book, but I was of opinion that it was desirable to go thoroughly into detail in this chapter, for the reason that the apparently most trivial defects in house-drainage are often the cause of the most severe and yet insidious disease outbreaks; and without a thorough knowledge in this branch of Hygiene, the practitioner would be unable to arrive at the cause of much that is baffling. In connection with this chapter, those who are able, should visit the Parkes Museum of Hygiene, where they can practically study the various sanitary appliances, and see many of them in working order.

The progress of Bacteriology and the almost universal acceptance of a germ theory of infectious disease, seemed to point to a chapter on the Contagia and the Communicable Diseases, in which the most recent advances of bacteriological and etiological investigation should be very shortly summarised, as a desirable addition.

One view which I had constantly before me, was to provide a suitable work for those who are preparing for the Public Health Diplomas of the Universities and Medical Corporations; but its scope and arrangement are also such as to render it, I trust, well fitted for students in medicine and medical practitioners, who cannot afford, now-a-days, to be without some knowledge of the science that has so strongly aroused the interest of the general public. The work may also prove of value to the candidates in the Advanced and Honours Stages of the Hygiene Examinations of the Science and Art Department.

In conclusion I wish to acknowledge the kindly help and advice of numerous friends; more especially am I indebted to Dr. J. H. E. Brock for his assistance in the revision of the proof-sheets.

L. C. P.

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HYGIENE AND PUBLIC HEALTH.

CHAPTER I.

WATER.

WATER is a prime necessity of life. Without it terrestrial animal and vegetable life must cease to exist. The earliest settlements in all countries were therefore made in the neighbourhood of water. Towns and villages sprang up on the banks of streams and rivers, on the shores of lakes, and in the neighbourhood of springs; or water was obtained from the soil around these early settlements by shallow excavations or wells. Any method of bringing water from a distance was then unknown. In modern times sites for dwellings are not necessarily limited to a small area around a natural source of water. Our engineering knowledge enables us, on the one hand, to obtain water by means of wells and borings from great depths beneath the surface of the earth, and on the other to convey water from great distances by means of conduits to the places where it is required.

This latter method was well-known to the ancient Romans, many of whose aqueducts and reservoirs are—after the lapse of many centuries—still standing, and serve to fulfil their original purpose. It must be remembered, however, that it was not until many years after the city was built that Rome was supplied with water from the surrounding hills by aqueducts. When the river Tiber, the original source of water-supply, became much polluted, and the springs and shallow wells in the city became insufficient, the first aqueduct—known as the Appian from the then consul—was commenced, about the year 312 B.C. or 441 years after the building of the city. Rome was doubtless founded upon the Tiber for the convenience of the water supply from the river. At the height of its prosperity, about 600 years after its foundation, the city was supplied with water by means of 9 aqueducts. The total supply per head was certainly not less than 300 gallons daily for a population of about 1,000,000 people; the greater portion of this vast supply of water being required for public baths and fountains.

London is another instance of a settlement founded originally on the banks of a river, and spreading subsequently away from the neighbourhood of the river only in those directions where a water-bearing gravel overlaid the impermeable London clay. The bed of gravel being of but slight thickness—10 to 30 feet—water was easily reached by shallow excavations or wells; whilst at some places springs flowed out where the gravel terminated, as at Bagnigge, Holywell, and Clerkenwell. Fifty years ago, parts of London where the clay came to the surface, and which are now densely populated owing to the introduction of a public water supply, were quite uninhabited.

There is reason to believe that the ancient Egyptians and the Chinese from a remote antiquity obtained water from great depths below the surface of the earth by means of Artesian wells, the water flowing out at the mouth of the well; but the practice of making deep borings in search of water was not introduced amongst western nations until comparatively recent times.

Sources of Water—Collection and Storage.

All natural sources of water are derived from the rain and snow which fall on the surface of the earth. When the rain has reached the surface of the ground, it is disposed of in the following ways:—a portion (*a*) is evaporated; another portion (*b*) flows off in the direction of the inclination of the surface; whilst a third portion (*c*) sinks into or percolates through the interstices of the soil.

The amount of rain that evaporates depends upon the temperature of the air. The higher the temperature the greater the evaporation. The water, or fallen rain, that does not evaporate, either flows off the surface or sinks into the soil. If the inclination of the surface is *nil* or only very slight, and the soil is of a porous nature, the larger portion sinks into the soil or *percolates*. If, however, the inclination of the surface is great and the soil is not porous, but more or less impermeable to water, the greater portion of the unevaporated rain flows down the incline. It is this portion which forms or helps to swell the brooks, streams, and rivers, which are the natural drainage channels of the locality.

The portion that percolates, after a certain deduction that must be made for the moisture absorbed by the roots of vegetables and grasses growing on the surface, which is subsequently evaporated from their green leaves, helps to form and renew the underground sources of water. These are made available to man by natural outlets as springs, or by artificial tappings in their subterranean depths through wells and borings. In very porous soils such as pure sand or coarse gravel, the rain so rapidly sinks into the interstices of the soil, that the evaporation even in summer is but slight. In nearly all other soils, however, the amount of rain evapodrate greatly exceeds the percolation even in winter.

Rainfall.

The rain that falls on the roofs of houses can be collected and made available as a means of water-supply. To calculate the amount of water supply per head from this source, we must know the amount of roof space per individual—(the slope of the roof must not be taken into account, but merely the area of horizontal surface covered by the roof)—the average amount of yearly rainfall, and the average amount of evaporation of the rainfall. As the roofs of houses are—or should be—quite impermeable to water, there is no percolation or sinking in of the fallen rain.

The amount of yearly rainfall varies considerably in different parts of England. In the Eastern Counties the average is less than 25 inches per annum. Throughout the remainder of England the average is from 30 to 40 inches per annum, with very much larger amounts in the mountainous and hilly districts of Devonshire, Wales, Cumberland, and Westmoreland (60 to 200 inches per annum).

The amount of evaporation from the surfaces of roofs may be taken as averaging throughout the year 20 per cent. of the rainfall. The evaporation is greatest where the rainfall is least and *vice versâ*. If the amount of roof space per head in a town is 60 square feet, and the rainfall 30 inches in the year, deducting one-fifth for evaporation, 207,360 cubic inches of rain (= 120 cubic feet or 748 gallons) is the amount available for each person in a year, which is equal to about 2 gallons daily.

This is the amount available from the rainfall—30 inches—of an average year. It has been found from a great number of records of rainfall extending over a long series of years in different places, that the rainfall in the driest year is one-third less than the average fall, whilst in the wettest year it is one-third greater than the average. So that in a very dry year, in the example above given, the amount of water available may be only $1\frac{1}{3}$ gallons daily per head, whilst in a very wet year it may be $2\frac{2}{3}$ gallons.

Rain is also sometimes collected from prepared surfaces of ground. The surface of a certain area of land in an exposed situation is rendered impermeable by a covering of slates, asphalte, or cement, and sloped towards an outlet pipe or pipes leading to a tank or reservoir. In calculating the amount of water that can be obtained from such a surface, the same factors must be taken into consideration, as has been explained above. In any such inquiry, calculations may be facilitated by remembering that one inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons) on each square acre.

Rain, as it leaves the clouds, is water pure and simple, free from all foreign ingredients. In its passage through the air to the earth, it absorbs various impurities—gaseous and suspended. It becomes highly aerated, absorbs ammoniacal salts, nitric and nitrous acids to a small amount, and in the neighbourhood of the sea chloride of sodium. The rain falling in towns is found to have absorbed sulphurous acid—always present in the air of towns from combustion of coal and coal gas—and to contain numerous sooty particles.

From the observations made at Montsouris, near Paris, by Dr. Miquel, it also appears that the rain washes out of the air countless bacterial and fungoid organisms and their spores. The rain which first falls in a shower, and that which falls after a period of dry weather, contain far larger numbers of bacteria than that which falls later on in a storm, or succeeds the first shower: 200,000 germs per litre is not an unusual quantity under the first set of circumstances. During the warm months of the year, the number of bacteria in the rain are greatly in excess of those found in rain falling in winter and early spring. The greater number of the organisms in rain are micrococci. All the organisms (micrococci, bacilli, bacteria) found in rain exist to a larger extent in the form of germs or spores than in the adult state. Besides bacteria, pollen of grasses and flowers, microscopic plants such as *protococcus pluvialis*, and spores of fungi are found in rain; the latter being sometimes in sufficient quantity to cause a localised fall of what is known as "coloured rain."

Rain is thus seen to be a great purifer of air; for it washes out of it gaseous and solid impurities—organic and inorganic. For this reason also the rain which falls in the impure smoke and soot-laden atmosphere of large towns is unfit to drink.

When roofs are used as collecting surfaces for rain-water, the first portion of rain which falls and descends from the roof should be rejected, as it is liable to be much polluted with soot, vegetable matter (leaves), and animal matters (excrement of birds, etc.) washed off from the slates or tiles. After the first washing, the remainder of the water may be collected and stored. Robert's Rain Water Separator effects this purpose by allowing the first portion of water that passes through the apparatus to run to waste through a pipe at its base. After a certain time, the apparatus, which is balanced on a pivot, cants over, owing to its centre of gravity being altered when nearly full of liquid, and the water escapes from the outlet below into another pipe, which conducts it to a storage cistern. Rain-water should always be stored in as pure a condition as possible; otherwise the storage receptacle becomes coated with foul matters, which putrefy and poison the water.

Rain-water is especially useful for cooking and washing on account of its *softness;* that is to say, its freedom from the salts of lime or magnesia in solution. When these salts are dissolved in a water they render it *hard.* Hardness is usually reckoned as so many grains of chalk or carbonate of calcium per gallon of water. A water containing more than ten grains of chalk or its equivalent in other salts (sulphate or chloride of calcium, carbonate of magnesia) to the gallon, is said to be hard. Hardness, due to the presence of carbonate of calcium, which is chiefly held in solution in the water by its combination with carbonic acid as a bicarbonate, is said to be *temporary;* for when the water boils, carbonic acid is driven off, and the chalk, no longer able to remain in solution, is precipitated.

It is this deposit of chalk which causes the fur on the bottom and sides of boilers and kettles. When meat or vegetables are cooked by boiling in hard water, a certain amount of the same material is deposited on their surfaces, which either hinders the proper penetration of the heat into the interior, or prevents solution of the soluble materials when this is desired. The fur lining is also a non-conducting material, and prevents the passage of heat from the fire to the contents of the boiler or kettle, thus causing a waste of fuel.

Great waste of soap too is caused by the use of hard water in washing; and this results from the presence of all the salts causing hardness—the chloride and sulphate of lime, and the salts of magnesia, which cause *permanent* hardness (as they are not deposited by boiling), as well as the chalk which causes temporary hardness. In washing, it is necessary to produce a lather of the soap with water; but when the water is hard, the lime or magnesia combine with the oleic acid of the soap (hard soap is chiefly an oleate of sodium, soft soap an oleate of potassium) forming a curdy precipitate; and all the lime or magnesia of the water must be so deposited before a lather can be formed. Consequently a certain amount of soap is wasted. One grain of chalk wastes about eight grains of soap. It would be easy to calculate the yearly waste of soap in a household, if the degrees of hardness of the water were known.

The hardness of rain-water is generally less than half a degree; that is to say, there is less than half a grain of chalk or its equivalent salts to the gallon of water; hence its value for domestic purposes. Rain-water should never be allowed to run to waste in country districts, where the water derived from other sources is hard. There is one great disadvantage possessed by rain and other soft waters, namely, their liability to dissolve lead, iron, or zinc, if left in contact with these metals. Consequently cisterns of lead, iron, zinc, or galvanized iron should not be used to store rain water.

Upland Surface-Waters.

In hilly districts, the water which flows off the hills in the form of rivulets and streamlets can be collected and stored by building a masonry wall or barrier across the outlet of the valley to which the streams converge.

By this method of collection in "impounding reservoirs," large artificial lakes are formed; usually at considerable elevations above the towns which they supply with water, and capable of holding a supply sufficient for several months.

The water supplied to Dublin is derived in such manner from gathering grounds at Vartry amongst the Wicklow hills, 26 miles from the city. It is one of the purest waters in the world, containing only 4·5 grains of solid matters per gallon, of which about one-half is due to peat (vegetable organic matter); its total hardness is 1·8 grains per gallon, of which 0·8 is permanent hardness. When first impounded, the water had a yellowish colour which became gradually darker, owing to the fermentation of the peaty matter in the reservoir, whereby its solubility was increased. But this coloration gradually grew less intense, and in 2 or 3 years time the water became colourless.

Peaty matter is very frequently present in the upland surface-waters of mountainous districts, often imparting a decidedly yellow or brownish hue to the water. It may be removed by filtering the water through beds of sand, as is done at Vartry (Dublin); but as it is really quite innocuous, this measure is often more a matter of expediency than of necessity. Nearly all the waters supplied to Irish towns from gathering grounds amongst hills and mountains are more or less coloured with peat.

Under the heading of Upland Surface-Waters may also be considered the waters derived from natural lakes in mountainous districts, of which Glasgow furnishes a good example. Glasgow is supplied with water from Loch Katrine, 34 miles north of the City. This water contains only 2½ grains of solid matters per gallon, of which about one-half is organic (peat), whilst the remainder is mineral. It has a very faint yellow colour. This beautifully soft and pure lake water, which replaced in 1859 the grossly polluted supply drawn from the Clyde, has been of inestimable advantage to Glasgow; not only by raising the standard of health of its inhabitants, but also by effecting an enormous saving in manufacturing and industrial pursuits, from the fact of there being but one grain of lime per gallon of the water instead of several. The saving in soap alone is estimated at £36,000 per annum.

Upland surface and lake-waters approach more nearly to the composition of rain-water in their comparative freedom from foreign ingredients—organic or mineral—than waters derived from any other source. Many of the manufacturing towns in Lancashire and Yorkshire are supplied with upland surface-waters.

The quantity of water that can be collected and stored in an impounding reservoir amongst hills, can be calculated with some approach to accuracy, if the area of the catchment basin, the average rainfall, and the average amount of percolation, evaporation, and flow of the rainfall off the surface, are known. Records of the rainfall, percolation, etc., extending over a long series of years are most useful for this purpose.

Streams and Rivers.

Streams near their sources, passing through uncultivated land on hills and moorlands devoid of human habitations, are good sources of water-supply: they form in fact those upland surface-waters which have already been considered.

Streams and rivers in their course through cultivated valleys, with towns and villages on their banks, furnish water which must always be regarded as *suspicious* from the health point of view, and in many cases as dangerously polluted.

The composition of river-water, as regards its mineral ingredients, is most variable. Fed from a variety of sources, by springs and streams in the uplands, by surface drainage, springs in their beds, and other streams and rivers throughout the whole of their course, rivers are a combination of spring and surface-waters, and present sometimes chiefly the characteristics of the one, sometimes those of the other. Most river-waters are hard waters, containing in solution the salts of lime and magnesia, which are washed out of the soil in the bed of the river by the solvent action of the dissolved carbonic acid in the river-water. But in some cases these salts are chiefly derived from the springs which feed the river and its tributaries. Thames water, for instance, contains 15 grains to the gallon of lime salts, or their equivalents causing hardness. The water of the Ouse at York contains 9 grains per gallon of inorganic salts.

But it is not these inorganic matters which cause river-waters to be looked on with suspicion, but rather those pollutions of animal origin to which all rivers, as being the natural drainage channels of the surrounding land, must be subject. The surface and subsoil drainage from manured land under cultivation, the slop-waters and the sewage from towns and villages, all flow into the river, which they pollute with organic matters, fresh or putrid, of animal origin, amongst which may be concealed the specific poisons of infectious disease or their germs. Towns, as a rule, draw their supply of water from a river above the spot at which the sewage of the town is discharged. But the intake of the next lower town on the banks of that river must necessarily be from a stream already polluted with sewage; and the question arises—Can a river once polluted with sewage, and with all the possibilities of specific disease contamination thereby introduced, ever be a safe source of supply below the source of pollution? and if so, Is the water purified by natural means, or must it be subjected to some process of artificial purification? This question has given rise to a controversy which has not yet been definitely settled. It may be discussed from the point of view of theoretical considerations or from that of practical results.

When sewage or other polluting liquids are discharged into rivers, they are more or less diluted with the river-water, the amount of dilution depending on the comparative volumes of sewage and river-water which are thus mixed together. If the river, into which the sewage is discharged, consists of clean and hitherto unpolluted water, the atmospheric oxygen dissolved in it, which is chemically much more active than the oxygen of the air, will, to a certain extent, oxidise the organic matters of the sewage. If, too, the dilution of the sewage with clean water is considerable, plant life is not interfered with, but continues to give off oxygen, reoxygenating the water, and enabling the process of purification by oxidation to continue. No doubt, too, as the oxygen dissolved in the water is used up, fresh oxygen is absorbed from the air. Besides water plants, minute animals (infusoria, anguillulidæ or water-worms, entomostraca or water-fleas, etc.) aid the process of purification by feeding on the organic impurities of sewage. These organisms are found in countless numbers in the polluted reaches of rivers. Fish too, if the pollution is not sufficiently great to cause much diminution of dissolved oxygen in the water, feed on some of the elements of sewage, and aid in the process of purification; and if the current is sluggish, or in the deep and quiet pools of a rapid stream, the suspended matters of the sewage will be largely deposited.

The result of all these processes is that, under certain conditions and within certain limits, streams and rivers which have been polluted are capable of undergoing a certain amount of self-purification by natural means. How far this self-purification extends, in other words, its greater or less completeness within a certain distance of flow, is still a matter of doubt. The Rivers Pollution Commissioners (sixth report) came to the conclusion, as the result of their experiments, that "the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidised. It will be safe to infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation." On the other hand, several eminent chemists have expressed their belief that a flow of even a few miles is sufficient to free a river of all trace of sewage contamination.

The truth of the matter appears to be, that under favourable conditions, when the dilution of the sewage with clean water is very considerable, and the oxidation and purification exerted by aquatic animal and vegetable life can have free play, a stream or river, especially if it undergoes agitation and exposure to the air by flowing over rapids or by falling over weirs, is capable of being so far purified, that, although it may never quite regain its original purity, it becomes at least very much improved. Practically, however, in this country, streams and rivers are not allowed a chance of self-purification. The pollution is almost continuous from their sources to their mouths.

When the river, into which sewage is discharged, is already much polluted, or if the dilution is not sufficiently great, oxidation and purification are brought to a standstill. The dissolved oxygen is greatly diminished in amount, animal and vegetable aquatic life is injuriously affected or destroyed, and putrefaction sets in. The bacterial agents of putrefaction are the only organisms which can flourish under such conditions; decomposition and fermentation of organic matters is started, with the production of foul gases; the bed of the river becomes silted up with decaying matters, which, buoyed up by gases, occasionally rise to the surface to sink again, and a most serious nuisance results. The process is one eventually tending to purification by resolution of complex organic bodies into their simpler elements, but in the meantime the effects of the process are most offensive.

A considerable rise of temperature will produce a like result on rivers which are having their purifying powers tested to the height of their capacity. Purification goes on so long as the weather is cool, but with a rise in temperature, bacterial growth is stimulated, and decomposition sets in, replacing the oxidising processes. This happened to the tidal portion of the Thames in the summer of 1884, resulting in a condition of things which the Royal Commissioners on Metropolitan Sewage Discharge stigmatised as "a disgrace to the Metropolis and to civilisation." In the North of England, the

Irwell and the Mersey are so polluted with sewage and manufacturing refuse from the towns on their banks, that purification by oxidation may be said not to exist in these waters, which carry their filth and refuse unacted on and unchanged to the sea.

Sewage in potable waters—waters intended for drinking—is chiefly dangerous from the fact of its containing, or being liable to contain, the specific poisons of disease. Cholera and enteric fever, diarrhœa and dysentery, we know to be sometimes spread by means of infected or polluted water. We have no evidence as to the destruction of the poisons of these or other diseases in running waters; but we have reason to believe that, even if they are not destroyed, they at any rate do not increase or multiply to any extent in polluted waters undergoing self-purification. If it were not so, London, which is so largely supplied with a filtered, but nevertheless polluted water from the Thames, would not exhibit so low a death-rate; for we can hardly suppose that filtration through sand or gravel can always effectually remove or destroy the countless disease germs which would be otherwise present in the water.

The process of storage and purification pursued by the London (Thames) Water Companies, on the efficiency of which the health and freedom from disease of so large a population depends, is as follows:—

The water taken from the river at Hampton is passed into a storage reservoir of masonry, capable of holding several days' supply. It is important that the capacity of this reservoir should be sufficiently great, both to obviate the necessity of drawing water from the river when it is in flood, and therefore very turbid, and to allow time for the clarification of the water by the deposition of all its suspended matters. The five companies supplying Thames water to London have storage reservoirs of an aggregate capacity of 516 million gallons, capable of holding 7·3 days' supply—the average daily supply being 70·5 million gallons. From the storage reservoirs the water passes on to the surface of the filter beds, which consist of layers of fine sand (average thickness, 3 feet) lying upon layers of gravel, fine above, but coarse below. In the coarse gravel are the open mouths of the outlet pipes, which convey the filtered water to the pumping stations, from whence it passes through iron mains to the metropolis or to a high level reservoir near London.

The depth of water on the filter beds is never more than two feet; the average rate of filtration per square foot of filter bed being $1\frac{3}{4}$ gallons per hour. The upper layers of fine sand must be frequently renewed, as they become choked with sediment. They are usually removed, and washed with water jetted from a hose under high pressure, before being used again in the filter beds.

The result of this filtration process is the production of a pure and wholesome water, which, whatever its tainted origin, has never yet been known to cause disease amongst its consumers. The quality of the water depends largely upon the efficiency of the filtering process, and as a matter of fact, the Chelsea and West Middlesex Companies usually supply a rather purer water than the three other companies (Southwark, Grand Junction, and Lambeth), the two first companies having larger storage capacity and greater thickness of fine sand in the filter beds than the others. The same fact has been brought to light in a different way by Dr. Percy Frankland, who has shown that the micro-organisms (harmless) present in unfiltered Thames water at Hampton are reduced in number on the average 97·7 per cent. by the storage and filtration which the water undergoes at the hands of the water companies, but that this reduction is largest in the case of those companies which have the largest storage capacity for unfiltered water, the greatest thickness of fine sand in the filter beds, the slowest rate of filtration, and the most frequent renewal of the filter beds—all these being factors of much influence on the chemical, as well as on the biological characteristics of the water.

The conclusion that we may come to then, in the case of the London water-supply from the Thames, is that, as long as it is efficiently filtered, it is pure and wholesome; but that the Thames is not really a safe source of supply, for should the filtering arrangements break down at a period of epidemic prevalence in the upper reaches of the river, disease would in all probability arise amongst the consumers of the water in London. The same may be said of any other polluted river used as a source of drinking water.

An interesting example of a water-supply derived from a foully polluted river is furnished by the town of Wakefield, which draws its water chiefly from the Calder — a stream already intensely polluted with sewage and manufacturing refuse—about a mile below its own main sewer outlet into the river. This water, taken from a stream in a black and putrescent condition, is filtered by passing it through sand and magnetic carbide of iron. The filtered water, although undoubtedly improved, is still grossly contaminated with organic matters in solution.

The yield of a small stream, or water-course, may be approximately ascertained by observing the average width and depth of the stream over a portion of the channel where it is pretty uniform. The yield is found by multiplying the area thus obtained by four-fifths of the surface velocity in this portion of channel. If the whole stream is damned up and made to pass through a trough of known area and length, through a sluice of known size, or over a weir in which a rectangular notch is cut, the discharge of water can be estimated by any one of these methods with great nicety (*Parkes' Practical Hygiene*, 7th. Edition).

Springs.

As previously described (p. 3) some of the rain which falls on the surface of the earth evaporates; another portion flows off the surface; whilst the remainder percolates or sinks into the interstices of the soil. In its passage through the soil, the portion of rain that percolates absorbs carbonic acid from the ground air, which is very much richer (250 times) in this gas than ordinary atmospheric air. This water holding carbonic acid gas in solution is capable of dissolving some of the mineral constituents of the rocks over which it passes.

The most important minerals found in underground waters, issuing as springs, or derived from deep wells, are :—calcium carbonate from chalk, oolite, limestone, and sandstone; calcium sulphate from the same strata and from selenite; magnesium carbonate and sulphate from magnesian limestones; iron from the greensands and from the new red sandstone; and salts of sodium or potassium from sandstone rocks and other strata. In some springs, derived from underground waters at great depths below the surface of the earth, the mineral constituents of the water are so excessive in amount as to render it quite unfit for drinking, but valuable for medicinal purposes. The temperature of such springs is also often high. There can be little doubt that the water giving rise to these springs is, in many cases, forced out of the earth by the pressure of confined or expanding gases. But the origin of most of the springs which afford a pure and wholesome water for ordinary use may be explained in a different manner.

The rain which percolates into the porous strata (sand, gravel, chalk, sandstone, etc.,) at the surface of the earth, sinks through these strata by the force of gravity until it reaches—as it usually does at a greater or less depth—an impermeable stratum of hard rock, such as clay. Upheld by this stratum, the water accumulates and forms those underground reservoirs which supply the springs and wells. This underground water does not always stand at the same level. It is constantly rising and sinking, and in most years these variations of level are fairly regular, both as to amount, and as to the season of the year at which they occur. The highest level is usually reached in February or March, whilst the lowest occurs in October or November. The cause of these variations must be looked for in the circumstances attending the rainfall.

In districts having an average rainfall (25 to 30 inches per annum), the amounts of rain that fall in summer and in winter are very nearly equal. But in the summer months (April to September) the amount of rain that percolates is very small; it is only one-seventh of the summer rainfall in chalky soils. Nearly all the rain that falls in an average summer is evaporated from the surface of the soil or from the leaves of plants. The consequence is that the underground water is not replenished from the surface, and its level sinks. In the winter months (October to March) considerably more than half the rainfall percolates in chalky soils, the remainder being lost by evaporation. The underground water begins to rise usually in November, if percolation has commenced in October, and continues to rise until it attains its maximum in March. The following table shows the average rainfall and percolation in chalky soil. The observations were made by means of a soil guage at Nash Mills, Hemel Hempstead, and cover a period of over 29 years.

Winter.			Summer.			Entire Year.		
Rain.	Percolation.	Difference or loss.	Rain.	Percolation.	Difference or loss.	Rain.	Percolation.	Difference or loss.
13·33	8·11	5·22	14·09	2·18	11·91	27·42	10·29	17·13

Occasionally it happens, as in 1879, which had a very wet summer, that the underground water rises during the summer months. But such years are exceptional.

There is always a certain amount of percolation in the summer months, and this varies within rather wide limits. In some years it is *nil*, in other years it is– as in 1879—as great as the evaporation (over 12 inches). The reason of this appears to be, that the soil (chalk in this case) is able to evaporate about 12 inches of rain in the 6 summer months. If the summer rainfall is much less than 12 inches, there is no percolation at all; but if the rainfall exceeds 12 inches, the difference percolates, and helps to replenish the underground waters. In the chalk, as we have seen, about 37 per cent. of the entire rainfall percolates; in the new red sandstone about 25 per cent.; in the magnesian limestone 20 per cent.; whilst in the loose sands and gravels about 90 per cent. of the rainfall is said to percolate.

The underground water is not only constantly changing its level, but it is also always moving slowly towards its natural outlet. The water tends to find its own level according to the law of gravitation; not rapidly but slowly, owing to the friction and capillarity which obstruct its passage through the interstices of the rocks or soil. The outlet may be into the sea, or a river, or by springs on a hill side, at a much lower level.

It has been found by observations on deep wells, near to, and at varying distances from the outlet of a body of underground water, that it has a curved surface from its outlet to its highest levels. The curve rises steeply from the outlet, but gradually becomes more horizontal as the distance from the outlet increases, (fig. 1). The variations in level between high and low underground water are small near the outlet, whilst they gradually increase as the distance from the outlet increases. The higher the level of the underground water, the greater is the fall from its highest point to the outlet, and consequently, the larger the volume of water discharged at the outlet.

Springs are formed by the "cropping out" on the surface of the earth of the impermeable stratum which holds the underground water up, *i.e.*, prevents it from sinking further into the earth. They are natural outlets of underground water, and are usually divided into "main" and "land" springs.

Land springs are the outlets of limited collections of underground water, formed in superficial beds of sand or gravel overlying an impermeable stratum of clay. They are often intermittent, ceasing altogether to flow during the summer, when the underground water is exhaustéd, and beginning again in the autumn very soon after percolation commences. Intermittent springs are also formed where a valley cuts across the highest levels of a large volume of underground water, so that the spring flows only for a short period of every year—usually in February or March—when the highest water line of the underground water is tapped by the depression of the valley (fig. 1).

Main springs are the deep-seated springs issuing from regular geological formations, such as chalk, oolite, sandstone. They are usually perennial, flowing all the year round, but exhibit well marked seasonal variations, their volume increasing in winter, when the underground water level stands highest, and the fall to the outlet is greatest.

Springs afford good sources of water supply for small communities, such as villages. Main springs are better than land springs, both because, as before stated, they yield water throughout the entire year, and because they are less liable to accidental pollutions, the great thickness of strata, through which the water percolates from the surface, effectually oxidising any organic impurities it may contain. Such spring-water is usually clear and sparkling, well aerated, and of nearly constant temperature throughout the year. It generally contains more or less of the salts producing hardness, and is, therefore, though palatable and wholesome for drinking, less well suited for washing, cooking, and manufacturing purposes, than the soft waters.

To guard against pollution, the surface of the soil around the point of delivery of a spring should be walled in, and the water conducted to the surface by a short pipe. In some cases it may be necessary to collect the water issuing from a spring, and to store it in a reservoir before distribution to the houses of the consumers.

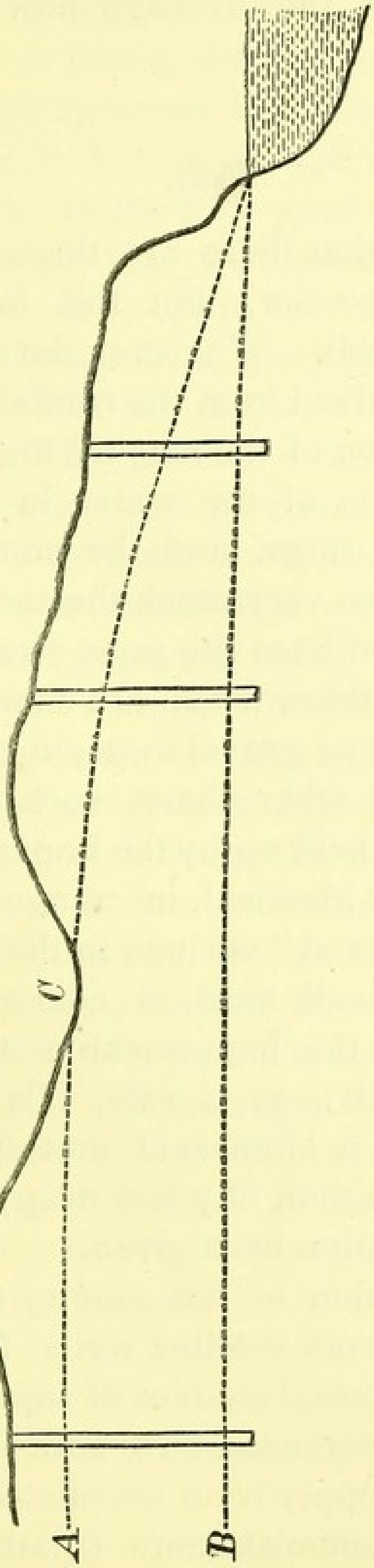

Fig. 1.—Underground Water Curves. *A*. High level. *B*. Low level. *C*. Intermittent spring.

The yield of a spring may be estimated by observing how long it takes to fill a vessel of known capacity. It is well to know the average flow throughout the year.

Wells.

It is usually said that there are three kinds of wells, *shallow, deep,* and *artesian;* but this last is merely a variety of a deep well. Whatever the depth of a well, the water in it is derived from the rainfall on the surface, and from that portion of the rainfall that percolates into the soil. The source of the water in wells is thus the same as that of springs, and the composition of the water in wells will be very much the same as that of the spring-water derived from the same strata.

Shallow wells are those which are sunk into superficial porous beds of sand or gravel overlying an impermeable stratum of clay or other dense rock. They tap the underground water held up by the impermeable stratum, and yield a water identical in composition with that flowing from the "land" springs in the neighbourhood. The depth of the well must, of course, vary with the vertical distance of the impermeable stratum from the surface of the earth; as a rule, this distance is not great, and in fact it is often said that shallow wells are those which are less than fifty feet deep; but it is better to keep to the definition here given.

The rural population of this country derives its water almost exclusively from shallow wells; formerly shallow wells were also the usual sources of supply in towns, but these, in nearly all instances, have now been abolished in favour of a public supply from unpolluted sources. The Rivers Pollution Commissioners (Sixth Report) stated that in their experience shallow wells are almost always horribly polluted by sewage and by animal matters of the most disgusting origin.

"The common practice in villages, and even in many small towns, is to dispose of the sewage and to provide for the water-supply of each cottage, or pair of cottages, upon the premises. In the little yard or garden attached to each tenement or pair of tenements, two holes are dug in the porous soil; into one of these, usually the shallower of the two, all the filthy liquids of the house are discharged; from the other, which is sunk below the water line of the porous stratum, the water for drinking and other domestic purposes is pumped. These two holes are not unfrequently within twelve feet of each other, and sometimes even closer. The contents of the filth hole or cesspool gradually soak away through the surrounding soil and mingle with the water below. As the contents of the water hole, or well, are pumped out, they are immediately replenished from the surrounding disgusting mixture, and it is not therefore very surprising to be assured that such a well does not become dry even in summer. Unfortunately, excrementitious liquids, especially after they have soaked through a few feet of porous soil, do not impair the palatability of water; and this polluted liquid is consumed from year to year without a suspicion of its character, until the cesspool and well receive infected sewage, and then an outbreak of epidemic disease compels attention to the polluted water. Indeed our acquaintance with a very large proportion of this class of potable waters has been made in consequence of the occurrence of severe outbreaks of typhoid fever amongst the persons using them" (6th Report).

The above passage indicates briefly the conditions under which shallow well-waters are usually drunk;

but it will be advisable to consider the sources of pollution of such well-water somewhat more in detail.

Where the level of the underground water is but a few feet from the surface, it is obvious that the surface-water, which may contain impurities, has but little chance of being purified by oxidation in its passage through the soil to the well. But the grosser pollutions that shallow well-waters suffer from, come, not from this source, but from leaking drains and cesspools in the vicinity.

Cesspools are but rarely made watertight, as they would then require to be frequently emptied. When sunk in a porous soil and merely lined with bricks without mortar or cement, the liquids soak away, and the solids—small in volume—so gradually accumulate that the cesspool can be closed over and need not be opened for years. The liquid sewage percolates through the soil and joins the undergound water below. As the underground water is—as before explained—slowly but steadily moving along in the direction of its natural outlet, the position of the well, in regard to the cesspool, is all important. Should the well be above the cesspool, the underground water flowing from the well to the cesspool, the risk of pollution is greatly diminished, so long as but little water is drawn from the well. If the well is below the cesspool, it must infallibly be polluted with the cesspool soakage. The direction of flow of the underground water can be usually determined from the contour of the surrounding country; and this evidence can be confirmed by observations on the height of the underground water at different places, as determined by the height of the water (above sea level or ordnance datum) in different wells, for the level of the underground water falls as it approaches its outlet, giving rise to a curve which has been already considered (see p. 21).

When, however, the amount of water abstracted is sufficiently great to cause a considerable depression of the water in the well, the conditions are altered; for the well then drains an area all around it in the form of a circle, that is to say, the water in the well is renewed not only from above—as regards the flow of underground water—but from below; and in such a case it would not matter what position the well had to the cesspool, if the cesspool was included in the area drained by the well, for pollution must inevitably occur. The distance within which a well draws water to itself, when its own water level has been depressed by pumping, depends on the amount of the depression and on the nature of the soil.

This distance—the radius of the circle drained by the well—is best expressed in terms of the depression. In fine sands and gravels, which offer considerable resistance to the passage of water, the distance varies from 15 to 39 times the depression. In the chalk, where fissures facilitate the passage of water, the distance is 57 times the depression. In very coarse gravel, which allows free passage of water, the distance is from 68 to 160 times the depression; and in the new red sandstone, where extensive fissures exist, the distance is 143 times the depression. These results are founded on observations made, chiefly abroad, by sinking borings at different distances around a well. They are very instructive, but require confirmation by extended observation.*

The surface of the underground water in the area of

* See Article on "Water," in *Our Homes*, by Rogers Field and J. W. Peggs.

the circle drained by a well depressed by pumping, has the form of a curve, analogous to the natural curve of the underground water, with steep vertical gradient near the well, but rapidly becoming more nearly horizontal as the distance from the well increases (fig. 2).

We have thus seen, that the conditions which determine the freedom or otherwise of a shallow well from cesspool or sewage pollution are:—(1) Its position as to cesspools or other sources of pollution, with regard to the flow of underground water; (2) the amount of depression of water level in the well which may be produced at any time by pumping; (3) the nature of the soil in which the well is sunk, as regards porosity and the easy passage of water. It is quite possible, if these conditions are attended to, to sink a well that shall be uncontaminable in or near a village, in which the shallow wells generally are horribly polluted with cesspool soäkage.

The well must be sunk in such a position as regards possible sources of pollution, that the underground water flows from the well to the sources of pollution. The distance of the well from such possible polluting sources should be from 100 to 160 times the depression of the water in the well that is ever likely to be produced by pumping, this distance varying with the nature of the soil. The mouth of the well should be closed over and the water raised by an iron pump; draw-wells where the water is raised by a windlass, chain, and bucket through an open mouth are liable to accidental contamination from refuse being thrown in, or animals falling in. To prevent contamination from impure surface washings, the mouth of the well should be protected by a coping, and the drainage water from the pump conducted away to a safe distance.

If the porous stratum in which the well is sunk is of

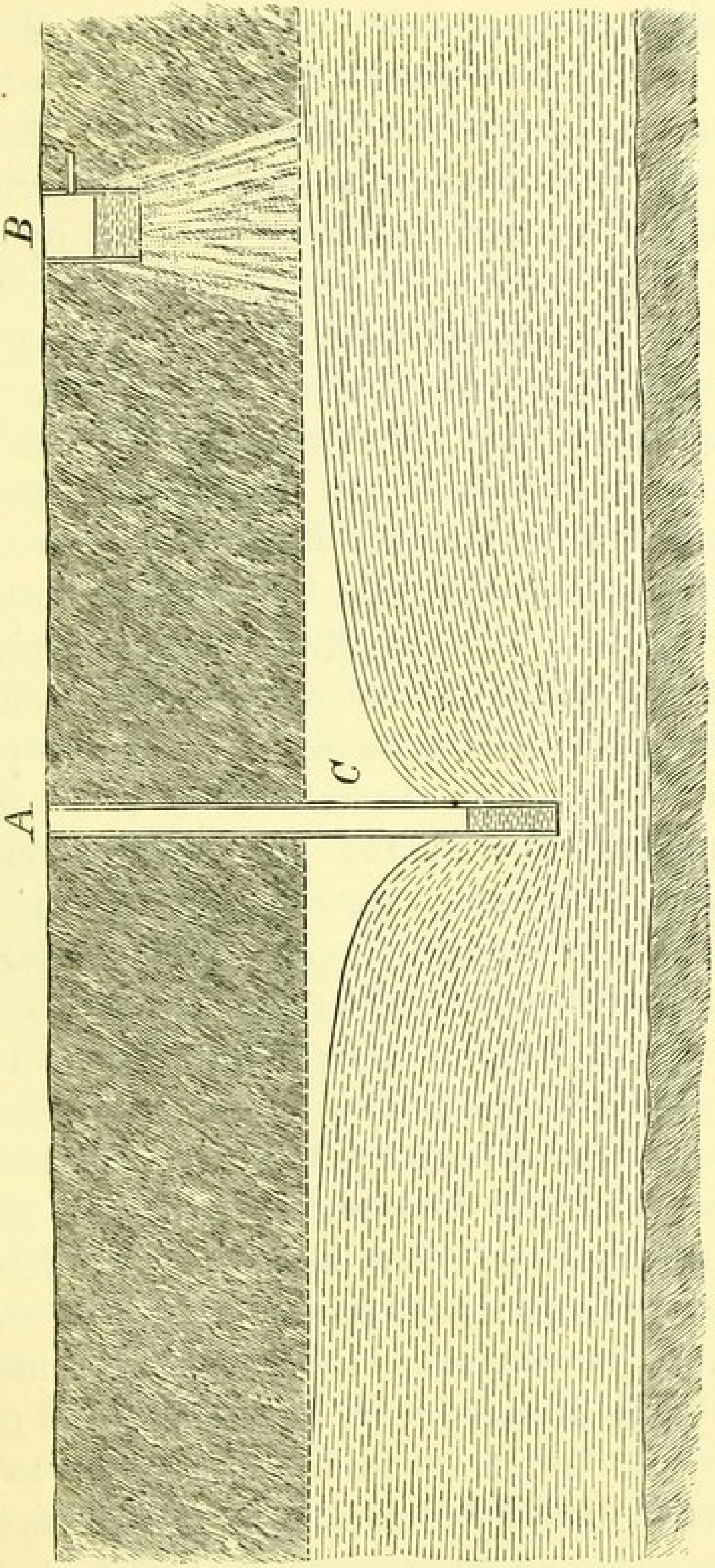

Fig. 2.—Depression of water in shallow-well by pumping. *A*. Well. *B*. Cesspool. *C*. Underground water curve (after Field and Peggs).

considerable thickness, the underground water being 30 feet or more from the surface, the sides of the well for this depth should be imperviously steined with brick-work set in and lined with hydraulic cement. If this is done, water percolating from the surface must pass through at least 30 feet of soil before entering the well. In its passage through the soil, the organic impurities in the water will be, to a certain extent, removed by oxidation.

It is a curious circumstance in regard to the grossly polluted waters of many shallow wells, that they are as a rule clear, sparkling, and very palatable. The organic filth from cesspools and drains, in its passage through even a few feet of porous soil, is filtered and deprived of suspended matters, but without losing its dangerous properties. The shallow well into which the filth percolates is found to furnish a water loaded with ammonia and chlorides—evidences of sewage (urine) contamination—with organic matters in solution, and with nitrates and nitrites, the oxidised residues of ammonia and organic matters, but yet, from its containing abundance of carbonic acid gas, sparkling and palatable. If such a water, however, is put in a bottle and kept in a warm place, it very soon becomes turbid, then putrid, and is found to swarm with bacterial life. Such wells too, after a heavy rainfall, are very liable to furnish a turbid and foul smelling water which nobody would think of drinking. The heavy rain washes foul substances in the soil, derived by soakage from manure heaps, middens, privies, or cesspools, straight into the well, no time being allowed for that filtering and partial purification by oxidation which does so much to give the well-water at ordinary times its pure but deceptive appearance.

Polluted shallow well-waters are usually excessively hard (both permanent and temporary hardness) and therefore unsuited for domestic purposes. The hardness is largely due to the polluting liquids which find their way into the well, but little being caused by the mineral salts present in the strata through which the well is sunk. Another source of pollution of shallow wells is the vicinity of graveyards. What has been already said as to cesspool pollution is quite as applicable to the dangerous pollution arising from this source, especially as regards the flow of underground water, whether it be from the well to the graveyard, or from the graveyard to the well.

Tube wells are contrivances for obtaining water from superficial porous strata by means of borings. They were largely used during the Abyssinian campaign, where the occupation of any piece of ground was necessarily temporary, the tube being quickly sunk and as quickly withdrawn. An iron tube with a steel nozzle and perforations at its lower end for the passage of water is driven into the ground by a driving weight or "monkey"; before it has altogether disappeared into the ground another length of tube is screwed on, and this is then driven into the soil. Successive lengths of tube are attached until a depth of 20 to 28 feet is reached when a hand pump is screwed on to the top, and the water pumped out. Difficulty is often experienced from sand blocking the lower part of the tube and the perforations. The sand must be dislodged by a clearing tool, or pumped out until a space free from sand is formed around the nozzle, and the water issues clear and bright.

Deep wells are those which are sunk to considerable depths in search of water through regular geological strata such as chalk, oolite, and sandstone. Those also are known as deep wells, which pass through a superficial porous bed and an underlying impermeable stratum to reach water-bearing strata at greater depths, though often at no great distance from the surface. Thus it may happen that a shallow well sunk 50 feet into a porous soil may be deeper than a deep well at no great distance away, which passes through the impermeable stratum upholding the water which supplies the shallow well.

If the sides of a deep well of this nature are properly steined with brickwork set in cement as far down as the impermeable stratum, surface waters and underground water resting on this stratum are entirely excluded, and the well is freed from those sources of pollution which so greatly contaminate shallow well-waters. Steining should also be applied to deep wells sunk through porous strata for the whole of their depth; in this way surface pollutions are compelled to pass through considerable thicknesses of soil before reaching the well.

The water which supplies deep wells has usually travelled a long distance since it fell as rain on the surface of the earth. The outcrop of the water-bearing strata on the surface may be many miles from the spot at which the well is sunk, as is the case with the deep wells in the chalk sunk through the London basin.

The London basin is interesting as an example of a geological formation with water-bearing strata in different rocks at varying depths from the earth's surface (fig. 3). Most superficially are the subterranean waters in the beds of gravel or alluvium of but slight thickness (10 to 30 feet) upheld by the London clay. These waters supplied the shallow wells which formerly formed so large a part of the water supply of London.

After boring through the London clay (100 to 400 feet

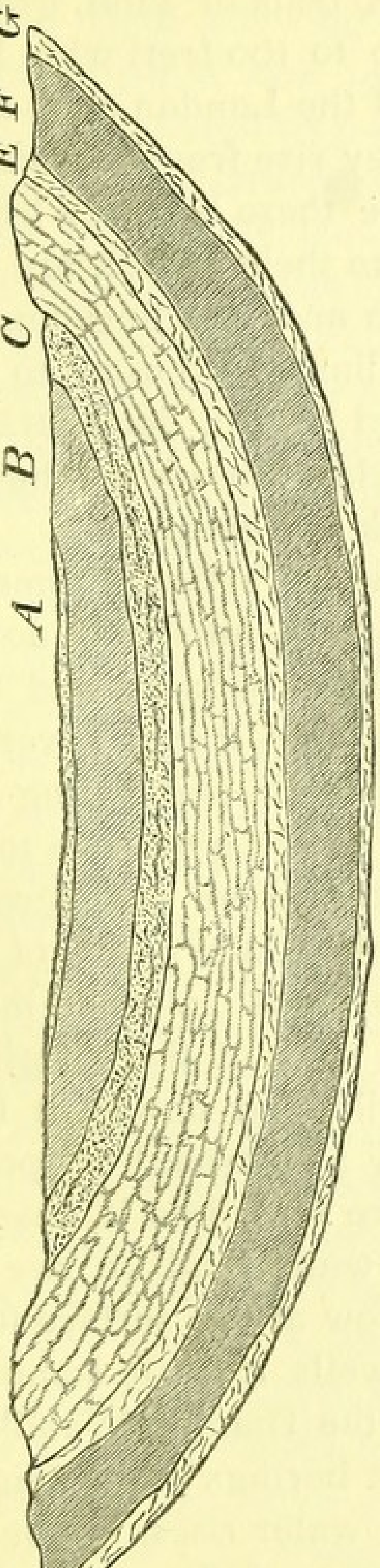

FIG. 3.—Diagrammatic Section through London Basin.

A. Surface gravel, brick-earth, or alluvium.
B. London clay.
C. Lower London Tertiaries—sands, gravels, and thin beds of clay.
D. Chalk with fissures.
E. Upper greensand.
F. Gault.
G. Lower greensand.

in the neighbourhood of London) water is again reached

—or was before these strata were exhausted—in the Lower London Tertiaries, beds of sand, gravel, or clay of variable thickness (20 to 100 feet) with limited outcrops beyond the edge of the London clay, and more or less surrounding it as they rise from the margin of the basin. The places where these beds are best exposed, and from which they take their names are Blackheath and Oldhaven, Woolwich and Reading, and the Isle of Thanet. Having such a limited exposure to rainfall, the water which accumulated in the deep strata of these beds under the London clay was soon exhausted, when numerous wells were sunk into them.

Beneath the Lower London Tertiaries comes the chalk, with its outcrop in the chalk hills and downs, north, south, and west of the Thames basin, and many miles from its centre. The outcrop forms a very extensive catchment area for rain, which, percolating through the joints and fissures of the chalk, gives rise to vast reservoirs of subterranean water in the underground extension of this rock beneath the tertiary beds of the London basin. As the London basin is hollowed into the form of a shallow trough, the sides of the trough being the outcrop of the chalk in hills and downs, it follows that the water in the chalk is also trough-shaped, and that when wells or borings are sunk into it near the centre of the London basin, the water tends to rise in the boring, and may even overflow at the surface forming true Artesian wells. Such wells exist in some of the low grounds of the valleys of the Thames, Wandle, and Lee; but as a rule, in the chalk borings in the neighbourhood of London, although the water rises, it does not reach the surface. In consequence of the number of borings drawing water from the chalk near London, the water level has been lowered; and borings have now to be made deeper than formerly. Owing to the joints and fissures in the chalk allowing a free passage of water, the distance which a well or boring drains, when its water level is depressed by pumping, is very great; and thus borings at considerable distances from one another are mutually affected by continued pumping in any one of them. If a boring in the chalk should not happen to open up any fissures or cracks, it may supply but a limited quantity of water, or none at all.

Beneath the chalk is the upper greensand in thin beds (10 to 30 feet) with a very limited outcrop around the edge of the chalk; and beneath this again the gault, a bluish clay with an average thickness of 130 to 200 feet. Under the gault lies the lower greensand in very thin beds often completely thinned out, and therefore absent. Although the greensands are rocks permeable to water, neither the upper nor lower beds have yielded water in any quantitity to deep borings in the neighbourhood of London. Their outcrop is very limited, with but a small exposure of catchment area for rain; and these formations appear also to thin out considerably in their underground extensions towards the centre of the basin. Near their outcrops in many places the greensands furnish abundant supplies of water.

Several borings made in or near London have passed through all the strata above mentioned into the primary rocks beneath. Thus, a boring at Meux and Co's brewery in Tottenham Court Road passes through *made ground* 22 feet, *London clay* 64 feet, *Lower London Tertiaries* 72 feet, *chalk* 655 feet, *upper greensand* 28 feet, *gault* 160 feet, *lower greensand* (?), *Jurassic* 64 feet, *Devonian (purple shales)* 80 feet, Total depth 1146 feet.* In making

* *Guide to the Geology of London and the Neighbourhood.* By W. Whitaker, B.A., F.G.S.

these borings it is usual to excavate a wide well-hole for some depth, from the bottom of which a bore-tube of small diameter is sunk. The water should rise through the bore-tube in sufficient volume to form a reservoir in the lower part of the well-hole, from which it can be pumped to the surface.

Artesian wells, so-called from the province of Artois in France where they have long been in use, are formed when a boring taps a subterranean reservoir confined in a permeable stratum by impermeable strata above and below; the permeable stratum having its outcrops on the surface at considerably higher levels than the surface of the ground where the boring is sunk. The subterranean reservoir is consequently basin shaped; and the water, when tapped at the lower part of the basin, strives to regain its level by flowing up the boring and spouting out at its mouth. The waters which feed these wells often come from a great distance, the outcrops of the permeable strata on each side of the basin, which are the catchment areas for the rain, being sometimes 60 or 70 miles from the well in a straight line. The well at Grenelle is 1800 feet deep, giving 656 gallons of water in a minute, with a temperature of 27° C. Artesian well-water is organically very pure, but may contain excessive quantities of alkaline salts, or salts of lime and magnesia, and it is usually also not well aerated.

The water supplied by deep wells is generally remarkably free from organic impurities, even when sunk in the midst of large cities. Nitrogen, as nitrates and nitrites, is usually present in deep well-waters; the other mineral constituents of the well-water depend chiefly on the strata through which the water has percolated, and on the solubility of the component elements of these strata by water charged with carbonic acid.

The yield of water from a well can be only ascertained by pumping down to a certain level, and observing the length of time required for the water to regain its original level.

Composition of Water from Various Sources.

The upland surface-waters from the igneous rocks and from the metamorphic and Devonian series are very generally peaty; but they are pure and soft, owing to the non-absorbent character of the rocks, and their freedom from soluble compounds of lime and magnesia. The waters from the millstone grits and coal measures, with which the manufacturing towns of Lancashire and Yorkshire are largely supplied, are also usually peaty, and contain rather more of the salts producing hardness, (chiefly permanent hardness) than do those derived from igneous and metamorphic rocks. Mountain limestone furnishes a somewhat hard and peaty water, as does also the calcareous portion of the coal measures.

The waters from the shallow wells given in the table, are all polluted waters—polluted by soakage from cesspools and sewers. The animal organic matters, in their passage through the soil from the source of pollution to the well, are to a certain extent oxidised, and converted into nitrates and nitrites. The large amount of chlorine in these waters also indicates pollution with urine; whilst the hardness is excessive, and is not derived from the strata in which the wells are sunk, but chiefly from the sewage pollution, as is clearly shown by the fact

COMPOSITION OF WATERS FROM VARIOUS SOURCES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

*(From the 6th Report of the Rivers Pollution Commission).**

		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness.			Remarks.
									Temporary.	Permanent.	Total.	
Rain water in open country.		4·22	·131	·026	·040	0	·059	·19	—	—	·5	
Upland Surface Waters.	From Igneous Rocks. Supply to Devonport from Dartmoor.	3·50	·104	·024	0	0	·024	1·25	0	·8	·8	Very turbid.
	From Metamorphic, Cambrian, Silurian, and Devonian. Thirlmere Lake.	2·66	·194	·004	·003	·002	·008	·52	0	·7	·7	Clear and colourless.
	From Yoredale and Millstone Grits and the Coal Measures. Sheffield water supply.	8·36	·356	·057	·001	·032	·090	·85	0	4·4	4·4	Turbid.
	From Mountain Limestone. Newcastle water supply.	23·40	·237	·062	0	0	·062	1·59	5·8	8·1	13·9	Clear.
	From the calcareous portion of the Coal Measures. Stockton and Middlesboro' water supply.	17·24	·180	·013	·001	0	·014	·90	8·6	3·6	12·2	Clear.

Shallow Wells	stone. Birmingham.	91·80	·440	·050	·080	3·149	3·271	11·60	13·0	30·7	44·3	palatable.
	In or upon chalk. Canterbury.	65·76	·249	·096	·165	1·707	1·939	5·18	22·9	14·3	37·2	Very turbid.
	In gravel resting on London clay. Bloomsbury.	276·5	·342	·191	1·550	18·179	19·646	18·80	34·5	106·0	140·5	Clear and palatable.
Deep Wells.	In Magnesian Limestone. Sunderland water.	44·18	·035	·030	0	·416	·446	4·17	·8	13·9	14·7	Clear.
	In New Red Sandstone. Liverpool, 453 feet deep.	32·0	·076	·033	0	·411	·444	2·87	2·1	12·8	14·9	Clear and palatable.
	In upper and lower Greensand. Cambridge.	79·20	·073	·030	·068	0	·086	7·60	17·4	23·3	40·7	Slightly turbid, slight odour of H_2S gas.
	In chalk. Gravesend, 200 feet deep.	36·52	·030	·009	0	·582	·591	2·40	20·0	7·9	27·9	Clear and palatable.
Springs.	From the Oolites. Bath.	22·40	·140	·007	0	·100	·107	1·30	15·1	3·5	18·6	Slightly turbid, palatable.
	From the chalk. Watford.	32·36	·026	·012	·002	·422	·436	1·26	21·0	3·7	24·7	Clear and palatable.
	From gravel over London clay. Colchester, polluted.	154·70	·176	·057	·001	7·395	7·453	27·5	18·9	34·1	53·0	Clear and palatable.
Land drainage water from sewage farms, average composition.		64·02	·982	·191	·388	·756	1·266	6·36	17·56	15·40	33·09	
Sea water (average).		3898·7	·278	·165	·006	·033	·204	1975·6	48·9	748·0	796·9	

* Previous sewage contamination column omitted.

that the Canterbury well, sunk in chalk, supplies water less hard than that from the other two wells given. It is worthy of note that the water of the well in Queen's Square, Bloomsbury, although horribly polluted, was said to be clear and palatable.

Dolomite or magnesian limestone is a double carbonate of lime and magnesia. It is but little resorted to as a water-bearing stratum in Great Britain. The Sunderland water, which is derived from it, is very pure, but contains a rather large amount of permanent hardness. The new red sandstone, being a porous and ferruginous rock, acts as a powerful filter and oxidiser upon the organic matter in the water that percolates through it. It also contains carbonate and sulphate of lime binding together the quartz sand of which it is largely composed, so that the water derived from it is usually moderately hard, but organically very pure. The greensands are porous and oxidising strata, containing, however, protoxide of iron, which exerts a reducing action upon nitrates and nitrites in the water, converting them into ammonia, and reducing sulphates with the resulting formation of sulphuretted hydrogen. Water from the greensands is organically very pure, but as it has often passed over or through chalk, it is usually hard. Deep wells in the chalk supply a very pure but hard water. The hardness, due to bicarbonate of calcium, is temporary, and can be removed by boiling.

All the deep well-waters given in the Table, with the exception of those from the greensand, contain a considerable quantity of nitrogen as nitrates and nitrites. These constituents are derived by oxidation from the organic matters originally present in the surface waters, which sink through the porous strata, and are effectually purified, before they reach the well, by the length of their passage, both horizontally and vertically, through these strata. Deep wells, when protected from surface drainage in their upper parts, are but rarely polluted, even when situated in the centres of towns. But it does occasionally happen, that liquid soakage from sewers or cesspools finds its way into fissures in chalk or sandstone, which conduct it to the water of the well, unfiltered and therefore unpurified, and pregnant with danger to the consumers. Deep wells in Liverpool and other places have been closed for this reason.

Spring waters present much the same characteristics as the water from deep wells sunk into the same strata as those from which the springs issue. The oolitic rocks consist largely of carbonate of lime, and being porous and absorbent like the chalk, are capable of holding enormous volumes of underground water. Spring water from the oolite closely resembles spring water from the chalk. Springs arising from strata of but small thickness, as surface gravel overlying clay, are liable to pollution from animal sources in the neighbourhood, from the fact of there not being sufficient thickness of filtering material to thoroughly oxidise and purify the polluting liquids, before they gain access to the subterranean springs.

QUANTITY.

The water supplied to a community must be good in quality and abundant in quantity. Impure waters are liable to cause injury to the health of those who drink them ; whilst deficiency of water means want of cleanliness with its ensuing discomforts and dangers.

Water is required for the following purposes and in the undermentioned quantities for each (representing average requirements):—

		Gallons per head daily.
Household	Fluids as drink	0·33
	Cooking	0·75
	Personal ablution	5·00
	Utensil and house-washing	3·00
	Clothes washing (laundry)	3·00
	Water-closets	5·00
Trade and manufacturing		5·00
Municipal	Cleansing streets Public baths and fountains Flushing and cleansing sewers Extinguishing fires	5·00
Total		27·08

The quantities of water given above, as required for the household, are those which are necessary to maintain a good condition of cleanliness. The 5 gallons for personal ablution would allow a daily sponge bath for each person. If each person has also a weekly general bath of from 30 to 40 gallons, 5 gallons extra per head daily must be added.

In towns, 5 gallons per head daily is found to be ordinarily sufficient for municipal purposes; and the same amount is required besides on the average for manufacturing and trade purposes. Water is also required for animals—drinking, washing, and cleansing of stables. About 16 gallons daily for each horse, and 10 gallons for every cow, are average requirements.

On the whole it may be said that not less than 30 gallons per head daily of the population should be supplied to every town. There will always be some waste in households from leaky taps and fittings, and this must be provided for. The greater part of the waste, however, takes place from the mains, before the water reaches the consumer. In some towns it has been found that as much as one-half or two-thirds of the total water-supply leaks out of the mains into the soil.

The amount of water actually utilised in the houses of a town varies enormously. In the houses of the poor the actual amount used may be only 2 or 3 gallons per head daily. This meagre amount is not only, or even principally, due to want of personal cleanliness amongst the occupants, but is far more often due to the limited quantity of water at their disposal, when the supply is intermittent and has to be stored in cisterns or water-butts, often of a size totally inadequate to the wants of the people who take their water from these receptacles.

The supplies per head in the various towns in this country vary greatly. London is said to have a supply of from 35 to 40 gallons per head daily; Glasgow has 50; Norwich, $14\frac{1}{2}$; but it must be remembered that these are not the quantities available to the consumers; for the amount lost in leakage through the mains is generally a considerable proportion of the whole supply, and is nearly always an unknown quantity.

Distribution.

The system adopted by the ancient Romans for conducting the water collected at the gathering grounds into their cities was the construction of masonry aqueducts built on arches, with a gentle incline to allow of a steady flow of water from its source to its outflow in the city. The aqueducts usually crossed the valleys on raised arches, but the Romans also knew how to construct inverted siphons of lead piping for the passage of the water across valleys. The remains of the reservoirs with which the inverted siphons were connected on either side of a valley are still to be seen in the neighbourhood of Lyons.*

The water supplied by public companies to towns in this country is now usually distributed from their reservoirs through iron pipes laid underground. Cast-iron mains are subject to much rusting and corrosion, especially when the water is soft. Many of these pipes have been found much weakened by corrosion at some places, and nearly blocked with accumulated rust at others, the water also being deteriorated in quality. It is now usual to coat these pipes with some material which is unacted on by water, such as hot pitch or coal tar, or with a vitreous glaze. The magnetic oxide of iron produced on the surface of the metal by Barff's process is also coming into use. The practice of calking the joints of these pipes with tow or gaskin next the interior of the pipe, and then running the joint with molten lead, was strongly condemned by the Rivers Pollution Commissioners as the water absorbs impurities from the tow and hemp. They recommended that the pipes should have turned and bored joints, or in the case of mains large enough for a man to enter, that the inside of the joint should be pointed with Portland cement.

An enormous amount of leakage takes place from water companies mains in many towns, from slight settling of the ground after laying, or from the vibration of heavy traffic causing fracture of the pipes and joints. It has been estimated that in London 15 gallons out of

* *The Water Supply of Ancient Roman Cities*, by W. H. Corfield, M.A., M.D.

the 35 supplied per head daily thus run to waste in the soil. The loss is especially great where the supply is constant and the mains always kept under pressure. If the spots at which leakage occurs could be known, the pipes could be easily taken up and repaired, but the difficulty is to find where the leaks are. This difficulty has been overcome by Mr. Deacon, who has invented a meter which can be used as a waste detector. One of these meters is placed on each district main; it registers the flow of water by day and night, and therefore the waste, for the water flowing through the main during the dead of night is not used by the consumers, but is running to waste. Having localised the waste to the district supplied by a district main, the exact spots where the leakages are taking place can be determined by the vibrations thereby produced in the nearest house communication-pipes, which can be distinctly heard on applying the ear to the pipe.

The house communication-pipes in nearly all towns are of lead, connected with the main by a brass screwed ferule. It has been thought that these lead pipes would be acted on by water, especially soft water, and that there might be danger to the consumers. Such has not been found to be the case, for although new lead pipes are undoubtedly acted on by soft waters, an oxide of lead being formed which rapidly dissolves again, yet, in the case of peaty waters, there is a deposit of vegetable matter as well, which prevents all further action of the water upon the metal. The Loch Katrine water acts most powerfully on lead, and yet no symptoms of lead poisoning have ever been observed amongst the population of Glasgow.

The hard waters, which contain salts of lime and magnesia, either have very little solvent action on lead, or they quickly coat the metal with sulphate, or basic carbonate of lead, which prevent further action. The soft, highly oxygenated waters containing organic matters, nitrites, nitrates, and chlorides, are those which have the most powerful action on lead. Where lead poisoning is feared, a block-tin pipe should be substituted for the lead pipe. Block-tin pipes enclosed in lead pipes are occasionally used; it is important that there should be no crack or fracture of the tin lining, otherwise galvanic action will be set up when the pipe is full cf water, and large quantities of lead will be dissolved. Polluted shallow well-waters have been known to have a very powerful and persistent solvent action on lead, probably from their containing excess of carbonic acid, which tends to dissolve the coating of carbonate of lead formed in the pipe or cistern.

It has lately been discovered that the varying powers of corroding lead, exhibited by soft waters of apparently identical chemical composition, are due to the presence or absence of silica in the water. When silica is present, even in the proportion of only half a grain per gallon, the action on lead is very slight. There must be no excess of alkali in the water, or this inhibitive action of silica is not displayed. By passing distilled water and other soft waters known to have a corrosive action on lead through a filter formed of layers of sand, broken flints, and pieces of limestone, enough silica is taken up to reduce the lead corrosive power to one-thirtieth. The waters of Huddersfield and Sheffield which have a considerable effect on new lead, have been rendered nearly inactive by passing them through filters constructed as above. Some of the solvent properties of these waters are, however, due to the presence of peaty acids (humic, ulmic, etc.). After the prolonged drought of 1887, the waters in the Sheffield reservoirs ran very low, the peaty acids—derived from the gathering grounds—were not diluted to the usual extent, and a severe outbreak of lead poisoning occurred in the town. It has been quite recently suggested by Mr. Power, in a report to the Local Government Board, that the biological characteristics of a water—the presence or absence of bacterial organisms—may exercise an influence over its "plumbo-solvent" properties.

Water companies supply water to their customers either on the constant or the intermittent system. Under the former, the mains are kept constantly charged with water under pressure, the house pipes consequently are also always charged with water, and no storage of water on the premises of the consumer is required. The only cisterns required in a house supplied with a constant service of water, are small cisterns or water-waste preventers for flushing water-closets, and a small cistern to supply water to the kitchen boiler. Under the intermittent system, the flow of water in the mains is stopped, except for a short period of every day, by the turncock. The house pipes are only charged with water when the water is flowing in the main, and consequently water must be stored for use on the premises when the pipes are empty. The merits and drawbacks of each system we will now proceed to consider.

The great fault of the *intermittent service* is that water must be stored on the premises of the consumer. Water stored in small receptacles, even under the most favourable circumstances, deteriorates; it loses its aerated character, becomes flat and insipid, and absorbs impurities from the air. In the houses of the poor, water is often stored in the most filthy receptacles—wooden butts and tubs rotten and decayed within, or in cisterns exposed to the air which are the receptacles of all sorts of filth and rubbish. No wonder that Sir R. Rawlinson has said, "the water that the poor people get is contaminated as far as water can be contaminated." Even in the better class houses, cisterns are often placed in the most improper places, as under stairs or floors, where dust and dirt fall into them, or inside water-closets, where the air is loaded with foul gases.

The same cistern is far too frequently used to flush water-closets as well as to supply drinking water, which may become dangerously polluted in this way (see Chapter II.).

Another method, by which drinking water in cisterns becomes liable to a very dangerous pollution, is the very general practice of connecting the "standing waste" or overflow pipe of a cistern with the drain or soilpipe of the house, or with the D trap under a water-closet. It may be that the overflow pipe has a S bend on it before its junction with the drain, but as the water in a trap quickly evaporates when not renewed—and the water in this trap can only be renewed if the ball-cock of the cistern leaks—little obstacle is presented to the passage of foul, and possibly infected, sewer air from drain, soil-pipe, or D trap, up the overflow pipe, where it escapes over the water of the cistern. This direct connection of the overflow pipe with the drainage system is said to be one of the chief causes of the spread of typhoid fever in towns (see Chapter II.).

Besides the danger of pollution of water in cisterns by sewer air, dust, soot, and accidental contaminations such as dead mice, birds, or cockroaches, the material of which the cistern is composed is an important factor as regards the purity of the water stored in it. Iron cisterns rust and discolour the water; zinc is rapidly dissolved by water and produces poisonous effects; lead is dissolved at first when the cistern is new, but rapidly becomes coated with a carbonate or sulphate of lead when the water is hard, or with a carbonate and oxide when the water is soft. These deposits form a lining which protect the surface of the metal from further action. It is for this reason that the inside of a leaden cistern should never be scraped when the cistern is being cleaned out. Galvanized iron is largely used for cisterns; they are generally perfectly safe, but have been known to give up zinc to the water. Slate is a good material for cisterns, but the cemented joints must not be repaired with red lead, when they leak, as they often do. Stoneware cisterns, though heavy, are very valuable, as they give up nothing to water. Water should never be left in contact with wood, as wood when constantly wet rapidly rots, and forms a breeding place for minute worms and other animal organisms.

To indicate briefly the conditions under which water may be safely stored in houses:—(*a*) the cistern should be of stoneware, slate, or galvanized iron; (*b*) it should be placed in a light and well ventilated position, and should be properly covered; (*c*) it must not be used to flush water-closets, but may supply the "intercepting" or waste-preventing cisterns, which should be used for this purpose; (*d*) the overflow pipe must be carried out into the open air to terminate as a warning pipe; it may end over the open head of a rain-water pipe if the cistern is in an upper storey, or over a trapped siphon gulley when the cistern is near the ground; (*e*) the cistern should be cleaned out at regular intervals.

Cisterns are occasionally used to supply water-closets which have regulator valves on the supply pipes. Although there is but little danger by this arrangement of foul air finding its way into the drinking water of the cistern, as the supply pipe is always full of water unless the cistern is empty, still it is better to break the connection altogether between drinking-water cisterns and water-closets.

Another disadvantage of the intermittent service is that the capacity of the cistern is often utterly inadequate—especially in poor houses—for the wants of the people who depend upon it as their only source of supply. So great is this deficiency of storage capacity in many parts of London, that the water companies erect stand-pipes in courts and alleys, which are connected with a main always under pressure.

The advantages of an intermittent over a constant service are that there is less waste inside houses, and that the service of pipes, taps, and fittings need not be so strong as for a constant service. This latter point has been disputed, as regards the pipes, on the ground that there is a greater strain on the pipes where the water is suddenly turned on and off with a common stopcock, than where it is slowly turned on or off by the screw-down tap used with a constant service. There is no danger, either, with an intermittent service of the high parts of the town being without water on account of great waste in the low lying parts, as sometimes occurs with a constant service.

The great merit of the *constant service* is that no storage is required on the premises of the consumer. The dangerous and filthy pollutions that are thereby avoided have been already considered. More than 150 towns in this country, including the greater part of the East End of London, have now a constant service of water, and the results have been most beneficial to the poor populations of these cities. The water drawn from the taps on the house pipes is clear, cool, and sparkling, in the same condition as it leaves the water companies mains, and the supply is—or should be—abundant and never failing.

In actual practice, however, in many cases, these advantages have been somewhat mitigated by errors on the part of both consumers and water companies. Unless constant inspection is exercised, and the taps and fittings in houses frequently supervised, there is great waste. This occurs especially in cases where an intermittent service has been changed to a constant service, and the old pipes and fittings have been retained. The company, to economize water, shut it off from the house pipes, and then no water is obtainable perhaps for many hours.

Not only this, but where water-closets are flushed by a pipe and tap direct from the house main, without the intervention of a cistern or water-waste preventer—a not unusual occurrence in poor neighbourhoods—there is great danger of foul air, or even liquid filth, being sucked up into the empty pipe when the tap is left unscrewed, and so finding its way into the water mains of a district. The suction is due to a partial vacuum being created in the water mains when the water is turned off, owing to the water finding its way through leaky joints into the soil, or from the mains being emptied by taps on house pipes at a lower level. Such occurrences have given rise to epidemics of enteric fever at Croydon, Cambridge (Caius College), Sherborne, and other places. They illustrate the absolute necessity of breaking the connection between water-closets and water mains by the interposition of a small cistern or water-waste preventer.

In other cases the companies try to economise by insisting on the insertion of a throttle of very small diameter ($\frac{1}{8}$ to $\frac{1}{16}$ inch) into the house communication pipe, with the result that water merely dribbles out of the house taps when they are full on. In any case, screw-down taps must be substituted for common taps, and a screw-cock must be placed on the house pipe, where it enters the premises, to shut off the water in case of a pipe bursting. A drip-tap should also be placed on a pipe at the lowest part of the system, by which it may be emptied during frost. All the leaden service pipes of a house should be strong (12 lb. per lineal yard for one inch pipes, and 6 lb. per lineal yard for half-inch pipes), in order to withstand the constant pressure to which they are subjected. If pressure is maintained in the mains by pumping, and not by storage in a high level reservoir, greater power must be used in the morning of every day; this being the time when the largest quantities of water are drawn for domestic use. The difficulties in the way of the adoption of a constant service are doubtless great, but they—especially great waste of water—can be overcome by the use of Deacon's waste-water meter on the district mains, and by frequent supervision of house taps and fittings.

There is one danger to which water mains are subject, which has not yet been alluded to. If water mains and sewers are laid in the same trench, there is a possibility of foul matters, which have escaped into the soil from leaky sewers, being sucked into the water mains during intermissions in the service. Such intermissions are the daily occurrences of an intermittent service, and are often unavoidable with a constant service for executing necessary repairs to the pipes. The water and sewerage systems should be kept as far apart as possible. With a constant service the mains are always charged in case of fire; with an intermittent service much valuable time is often lost in finding the turn-cock.

Purification of Water.

It is highly desirable that the water supply of a community should, as far as possible, be free from all foreign and polluting ingredients. Nearly all waters derived from natural sources contain such ingredients, and the various processes of purification aim at their elimination. The foreign ingredients may be divided broadly into mineral and organic matters. As we have seen, most of the spring and deep well-waters, many shallow well-waters, and to a less extent the various river-waters, contain the salts of lime and magnesia, which render these waters hard. The removal of these salts, and the production of a softer water, is eminently desirable for economic purposes; and, occasionally, to improve the potability and wholesomeness of the water, when the salts are in great excess, or are chiefly of the kind producing permanent hardness. The removal of the organic matters, suspended or dissolved in water, is another and still more important object in any process aiming at complete purification. We shall now proceed first, to the consideration of those processes which are—or could be—undertaken on a large scale for the purification of water before its distribution to the consumers; and secondly, to such processes of domestic purification as may be undertaken on his own premises by the consumer, who has received his water from a public source, but is not satisfied with its quality, and desires if possible its still further purification.

What should be aimed at is, to procure at its source a water sufficiently good to require no artificial purification; but failing this, the water should be efficiently purified before its distribution to the consumers. It is certainly not wise to leave the purification to individual effort.

Purification on a large scale.—There are several processes (Clark's, Porter-Clark's, Maignen's, Howatson's, etc.) which aim at the removal of the mineral matters (the salts of lime and magnesia) from a water. The fundamental basis of them all is the addition of lime water. When a certain quantity of lime water is thoroughly mixed with a hard water, it combines with the carbonic acid holding the chalk in solution as calcium bicarbonate, with the result, that the new carbonates thus formed are precipitated, for they are insoluble in water. In this way chalk well waters of 20° of hardness may be reduced to 4° or 5°, and Thames water (16°) to 3° or 4°. The hardness, thus got rid of, is due to the precipitation of chalk, and chalk alone; it is temporary hardness, and the same effect would be produced on the water by an hour's boiling.

The working of the process (Clark's) may be described shortly as follows:—For Thames water, the proportion of lime to be used should be about $14\frac{1}{3}$ cwt. to each million gallons. The lime in the form of quicklime is first slaked with water in a tank, into which the water to be softened is gradually allowed to flow; thorough mixing must be ensured by wooden paddles or other mechanical means. The water becomes milky in appearance from precipitation of the chalk, and must then be allowed to settle for 12 hours, and subsequently decanted. Besides chalk, a certain amount of colouring and organic matters are removed from the water by this process. It is important that uncombined lime should not pass out with the purified water, as would be the case if lime were added in excess of that required to combine with all the carbonic acid holding the chalk in solution. To detect uncombined lime, it is only necessary to add a few drops of a solution of nitrate of silver to the treated water in a shallow white dish, when a yellow or brownish colour is produced if uncombined lime is present, but only a white precipitate of chloride of silver if there is none present.

Lime is also used as the precipitating agent in Porter-Clark's process; but the suspended particles of chalk are removed, not by settlement, but by filtration through a series of linen cloths in a filter press under high pressure. The process is expeditious, and very effective in removing lime and suspended matters from the water. It is one of the best means of softening water on a large scale.

Maignen's and Howatson's processes aim at removing from the water the salts producing permanent hardness (or some of them) as well as chalk. In Howatson's process, a solution of caustic soda is mixed with the water to be softened, in addition to slaked lime. The precipitated salts are removed by settlement as the water passes through a series of tanks. How much of the permanent hardness is reduced by these processes, we have no means of knowing.

The process of filtration through *sand and gravel* on a large scale as carried out by the London Water Companies has been already described (see p. 16). Suspended matters both mineral and organic are very effectually removed by sand filtration. Organic matters in solution are, to a small extent, oxidised in their passage through the filter bed, when the sand is clean and sharp. This action ceases when the particles of sand become encrusted with the impurities filtered out of the water; it is therefore most effective when the sand on the filter beds has just been renewed.

Magnetic carbide of iron has long been used at Wakefield for the purification of the highly polluted water of the river Calder. The filter beds of this material are covered with layers of fine or coarse sand of varying thickness. The magnetic carbide of iron has a very considerable effect in oxidising dissolved organic matters in the water, converting them into nitrates and nitrites; and this oxidising action is the greater the longer the water remains in contact with the particles of magnetic carbide, that is to say, the slower the filtration. The layers of sand effectually remove the suspended matters in the water, which thus reaches the magnetic carbide perfectly clarified. The sand beds must be frequently renewed, but the magnetic carbide need never be disturbed; all that is required is that the process of filtration should be intermittent, to allow of the proper aëration of the filter. These properties of magnetic carbide of iron render it one of the most valuable filtering materials now known. It should always be used with sand above it to clarify the water, otherwise the suspended matters would clog the pores and deteriorate the oxidising action of the filter.

Spongy iron, which is porous metallic iron, obtained by roasting hæmatite iron ore, has a very similar action on dissolved organic matters in water to that exerted by magnetic carbide of iron. Its oxidising power is said to be due to the fact that it decomposes water into its elements hydrogen and oxygen, the latter subsequently acting on the organic matters with which it comes into contact. Like the magnetic carbide, the longer the water remains in contact with its particles, the greater the purification; and like magnetic carbide also, it yields nothing to water except a little iron, which may be removed by filtration through sand. Spongy iron retains its properties for a long period, but requires periodical renewal, especially when used—as it generally is—as a mechanical filter for separating suspended matters from water, as well as a chemical filter. Spongy iron separates lead from water, but has no effect on other mineral matters. It has been used on the large scale at Antwerp and other places, and is only inferior to magnetic carbide of iron in its suitability as a filtering medium for town water supplies.

The property possessed by spongy iron and the magnetic carbide of yielding nothing to water—no phosphates or other germ nutrients—is a most valuable one; for the water, after filtration, can be stored for any length of time without any great deterioration from growth of microscopic organisms. The especial fitness of the magnetic carbide of iron for filtering a town water supply on a large scale lies in the fact that, when once the beds of this material are *in situ*, they need never be disturbed or renewed, and thus an enormous amount of labour and expense are avoided. The aeration by intermittent filtration, which is essential for magnetic carbide of iron, if it is to retain its oxidising properties, must not be practised with spongy iron as the latter cakes on exposure to the air.

Domestic purification.—*Distillation* effects a more complete purification of water than any other method which is practised. If the first portions of the distillate, containing volatile substances present in the water to be distilled, are rejected, a water free from all foreign ingredients is obtained. Its aeration, however, is deficient, but this aerated quality can easily be acquired by allowing the water to flow out of fine holes in the bottom of a cask, and pass through the air in finely divided streams. The distillation of sea-water is now largely carried out on board the ships of H.M. Navy and in the large steamships of the mercantile marine. As long as there is fuel on board, a most wholesome water can be obtained. Distilled water acts very readily on metals such as copper, zinc, iron, and lead; so it is important that the several parts of the distillation or condensing apparatus should not expose these metals to the action of the water.

By *boiling* water, carbonic acid is driven off with other volatile gases dissolved in the water, and chalk (temporary hardness) is deposited at the bottom of the vessel. The water is therefore softened. We have the strongest reason for believing that distillation and boiling—raising the temperature of the water to 212° F.—effectually destroy all organized living matter in the water except the spores of some bacteria. There can be little doubt but that the specific poisons of cholera, enteric fever, and of other diseases, occasionally propagated by means of impure drinking water, are effectually destroyed by even a few minutes' boiling. The spores that resist the temperature of boiling water are, seemingly, not disease germs, but merely the immature forms of harmless species; for experience has shown over and over again that water, and other fluids mixed with water, such as milk, in which the existence of poisons capable of producing enteric fever, cholera, scarlet fever, or diphtheria, was almost undoubted, have been rendered harmless by a few minutes' boiling. The exact temperature at which specific disease poisons are destroyed is not known. Possibly at considerable elevations above the sea level, where water boils at several degrees under 212° F., boiling would not destroy pathogenic organisms.

To completely sterilise water or any other fluid, it is necessary to boil it, or merely raise the fluid to a temperature of 212° F. without actual ebullition, for a short period (half an hour) on three or four successive days. In this way, the spores, which escape destruction by the first boiling, have time to develope into adult bacteria, which are destroyed by the next boiling, and so on, until all the successive crops are disposed of. Boiled water is flat and insipid, and should be aerated before being drunk.

Alum is sometimes employed as a purifying agent. It is much used in China, where the turbid waters of the large rivers are extensively drunk after the addition of a little alum. When added to water containing chalk in solution, it forms a bulky precipitate of aluminium hydrate, which falls to the bottom, carrying with it suspended and floating matters. It has little or no effect on organic matters in solution in the water. About 6 grains of alum to the gallon of water is the right proportion.

Other substances are occasionally added to water, such as perchloride of iron, sodium carbonate, and potassium permanganate. They have but little effect in purifying a foul water; and if the water is pure they are not wanted.

Filters.—Domestic filters are probably more often a source of pollution of the water than otherwise. It is usually considered that a filter requires no attention; it is consequently but rarely cleaned; the filtering material is never renewed; and its pores become clogged with putrescible organic matters, which form a suitable nidus for the growth and development of living organisms, that contaminate the filtered water. It is not unusual, under such circumstances, to find a considerably larger proportion of organic matter in the filtered water than was present before filtration.

This is especially the case when *animal charcoal* is used as the filtering material. This substance is prepared by calcining crushed bones in closed vessels; it is extremely porous, and exerts considerable oxidising action on dissolved organic matters in water, and bleaches colouring matters in solution. These properties, however, are evanescent, and rapidly disappear if the charcoal is not cleaned or renewed, especially if the water filtered through it is somewhat impure. Not only this, but the charcoal yields to water phosphate of lime, of which it is largely composed. The phosphate favours the growth of living organisms; so that water must neither be kept too long in the filter, nor must it be stored for use after filtration. Animal charcoal has very little action on fresh egg-albumen; it has been reasoned from this circumstance—and probably with correctness—that animal charcoal does not prevent the passage of living disease germs through its substance. For these reasons filters composed of animal charcoal, whether in loose fragments or in compressed blocks, are not at all suited for domestic use. They require more care and attention than any domestic filter is likely to meet with.

Silicated carbon and *manganous carbon* block filters are largely used. They consist of animal charcoal compressed into blocks by admixture with silica or manganese. They do not yield so much phosphate of lime to water as the pure animal charcoal filters; but they tend to become coated with a layer of organic matter which clogs the open pores. The block should be brushed occasionally to remove the thin film coating it; and every 6 months, at least, should be purified by subjecting it to a red heat, or by boiling it in a solution of Condy's fluid and sulphuric acid. *Maignen's "Filtre Rapide"* consists of a strainer of asbestos cloth spread over a perforated porcelain cone. Powdered animal charcoal, or other filtering medium, is laid over the strainer. The delivery of water through this filter is very rapid, and the asbestos and powder can be easily renewed at very small cost.

Domestic filters are also made of *spongy iron*, *magnetic carbide of iron*, and *carferal*, this latter substance being a mixture of iron, charcoal, and clay. It has good oxidising properties, and yields nothing to water which is favourable to organic life; but its lasting powers are inferior to spongy iron and magnetic carbide. These three substances are the best materials for domestic filters, with which we are now acquainted. Bischof's Spongy Iron Filter has come largely into use. The water which has filtered through the spongy iron, is deprived of the iron it may have taken up, by passing it through fine gravel, and pyrolusite—a crude oxide of manganese. The spongy iron must be kept covered over with water, and should be renewed about once a year. The Rivers Pollution Commissioners found that spongy iron filters, not only considerably reduced the proportion of organic matter in water, but also reduced the hardness—in some cases as much as 50 per cent. They also found that nitrates and nitrites were reduced by spongy iron, a small proportion of their nitrogen being converted into ammonia. In this way all evidence of previous sewage or animal contamination was destroyed (6th Report). Spongy iron and carferal may be used as mechanical filters to separate suspended matters, but, as previously explained, the magnetic carbide of iron should be used only as a chemical filter, to oxidise or remove dissolved impurities in the water. Carferal should be renewed about once a year; or it may be purified by exposing it to a low red heat.

In the *Pasteur-Chamberland* Filter, the water, under pressure, is passed through five or six solid porous earthenware cylinders. The filtered water is entirely freed from all suspended matters, including all kinds of bacterial organisms and their spores. The water is therefore sterilised; but the filter acting merely mechanically, there is no alteration in the chemical composition of the water. This filter is employed to sterilise pure waters for laboratory purposes, and might be so used for domestic purposes where the water is chemically pure. The bottom of the filter is connected with a main under pressure, the water issuing from the top.

The essentials of a good filter are:—

1. That every part of the filter shall be easily got at, for the purpose of cleaning or renewing the medium.

2. That the medium have a sufficiently purifying power, and be present in sufficient quantity.

3. That the medium yield nothing to the water that may favour the growth of low forms of life.

4. That the purifying power be reasonably lasting.

5. That there shall be nothing in the construction of the filter itself that shall be capable of undergoing putrefaction, or of yielding metallic or other impurities to the water.

6. That the filtering material shall not be able to clog, and that the delivery of the water shall be reasonably rapid (Parkes' *Practical Hygiene*, De Chaumont, 7th edit.).

The filters which fulfil these conditions the best are the spongy iron, carferal, and magnetic carbide of iron. The filters formed of loose particles give a more rapid delivery of water than the spongy iron and block filters. Filters should never be placed inside cisterns. In such positions they are neglected, their very existence being sometimes forgotten, with the result that they become excessively foul, and pollute the water they are intended to purify.

Distillation and boiling are the only methods of rendering a dangerously polluted water harmless. The Rivers Pollution Commissioners have expressed their opinion that all the methods of purification by filtration, whether carried out by water companies on the large scale, or by the consumer on his own premises, are inadequate to prevent the propagation of epidemic disease by water. Theoretically they may be considered some safeguard, but there is "not a tittle of trustworthy evidence to support such a view." The epidemic of enteric fever at Lausen in Switzerland, where the specifically infected water which caused the outbreak, had passed underground through the earth for a distance of half a mile, shows that filtration, which was found at the time sufficient to prevent the passage of finely ground flour previously mixed with the water, was not capable of destroying or removing the specific disease poison. "Nothing short of abandonment of the inexpressibly nasty habit of mixing human excrements with our drinking water can confer upon us immunity from the propagation of epidemics through the medium of potable water" (6th Report).

Diseases produced by Impure Water.

Dyspepsia and diarrhœa.—Waters with permanent hardness exceeding 7° or 8° often cause dyspeptic symptoms and diarrhœa, especially amongst those who are not used to them. The chlorides, sulphates, and nitrates of calcium and magnesium are the injurious salts. Similar symptoms are generally produced by drinking brackish water drawn from wells near the sea coast. Such water contains a large excess of chlorides of sodium, calcium, and magnesium.

Waters containing calcium carbonate in solution—the temporarily hard waters—are not in any way injurious to health. At the same time there is no reason to believe that the chalk waters are at all superior to soft waters for drinking. The idea once entertained that the salts in hard water aided the growth and nutrition of the bones in children, has been abandoned as untenable.

Diarrhœa, often of a severe choleraic type with violent purging, vomiting, and cramps, is occasionally produced by drinking water contaminated with sewage. But here again, it is principally amongst those who are unaccustomed to the water that these severe symptoms occur. Instances have been known where people have gone on drinking filthily polluted shallow well-water for years with no apparent bad effects. It has even been said that sewage waters produce a fattening effect on those who drink them. At any rate it seems certain that by long habitude the system becomes tolerant of many substances in water, which exert a marked effect on those who drink them for the first time. Whether the choleraic diarrhœa is due to the presence of a living germ in the water, or to dead and decayed organic matter in solution or suspension, is not yet certain. The former view is somewhat favoured by the fact that water contaminated, not with actual sewage, but with sewer gases—as when the overflow pipe of a cistern is connected with a drain or sewer—often produces severe diarrhœa. We cannot suppose that gases—*quâ* gases—can have much effect on the digestive organs, but in these gases we know that living micro-organisms may be floating, and that they may in this manner gain access to the water.

Vegetable matter, as peat, in water, is generally harmless. Large excess of such matters, especially when decaying, may produce unpleasant symptoms.

Infantile diarrhœa, which is so prevalent and fatal in the large towns of this country in the warmer summer months, appears to be due to water pollution in many cases. The polluting material, whatever its nature and origin, seems to be incapable of producing diarrhœa until the temperature of the water, stored in cisterns and reservoirs, has risen above 60° F. This fact likewise points to the presence of a living organism in the water as the cause of the diarrhœa—an organism which is inactive at low temperatures, but rapidly multiplies and acquires pathogenic properties when a suitable temperature is reached.

The same conditions of drinking water which produce diarrhœa in this country, often give rise to *dysentery* in hot climates. Dysentery may also be spread by the evacuations of patients suffering from this disease contaminating the water used for drinking. Dysenteric evacuations are believed to contain the specific poison of the disease.

Enteric fever.—This disease is more often spread by the medium of water than in any other way. The conditions of drinking water which are capable of producing dyspepsia, diarrhœa, or dysentery, cannot produce enteric fever. Enteric or typhoid fever is a specific disease;* it can only be propagated by a specific poison contained in the secretions and discharges of a patient ill of the disease. It is true that there are some persons who hold that enteric fever is not a specific disease and that it can arise *de novo*, by which is meant that enteric fever can be produced in man by the introduction into his body of ordinary filth—filth which has not received the specific typhoid evacuations, but which has by a fortuitous combination of circumstances not known and not understood, acquired the power of producing a disease which runs a definite course, with definite symptoms, and which confers immunity on the person once attacked for the rest of his life. The two strongest arguments against this view are:—(1) many instances have been recorded where people—even whole villages—have drunk fæcally polluted shallow well-water for years with impunity, until a case of enteric fever imported from without, has introduced the specific poison into the water, on which occurrence a wide-spread epidemic has begun; (2) it is practically impossible, when the origin of an epidemic of enteric fever is in question, to exclude the possibility of the presence of the enteric fever virus in the water or other substance credited with the outbreak. For all we know to the contrary, the specific poison of this disease may remain latent for years until some change in its surroundings and environment calls it again into a state of activity. Cases of the fever which to all appearance have had a *de novo* origin,

* This view is not shared by some army medical officers; for in tropical climates it is often impossible to connect an outbreak of typhoid with the contagion of a pre-existing case.

may have in reality been caused by a long latent poison springing again into activity.

Specifically infected sewage appears to have the property of infecting the air in contact with it; for outbreaks of enteric fever have been traced to pollution of water with sewer air, or sewer gases rising out of a sewer into which enteric fever evacuations have been discharged. Nearly all the evidence we possess points to the possibility of the discharges of a single patient infecting an enormous volume of water. This can only be explained by supposing that growth and multiplication of the specific cause of the disease takes place under suitable circumstances outside the body of the patient. In the outbreak at Caterham the discharges of a single labourer, who had the fever, must have spread through and infected an enormous volume of water in the wells and adits, which supplied the surrounding district. It has been stated that this infected water gave no evidence by chemical examination of any contamination.

Enteric fever spread by specifically infected water is remarkable in having usually a shorter incubation period than when spread by air similarly infected, and in attacking a larger number of those susceptible persons who undergo the risk of infection. Enteric fever discharges are generally believed to be infectious from the first; it is not necessary that decomposition should have set in, before their infectious properties are capable of development; but on the other hand, putrefactive changes do not in any way destroy or mitigate the contagion.

Asiatic cholera.—This is a specific disease, spread by a specific virus contained in the evacuations of a person ill of the disease. There is now abundant evidence that cholera is often propagated by means of drinking water to which the specific disease poison has had access. This is not the only mode of spread of the disease, no more than it is of enteric fever; but the evidence which is constantly accumulating, points strongly to the conclusion that, as for enteric fever, so for cholera, specificially infected drinking water is one of the most frequent methods of its propagation. Such evidence was first obtained in this country during the cholera years of 1848-49, and subsequently during the outbreaks of 1854-55, and 1865-66; but even in those parts of India where the disease is endemic—epidemic outbursts occurring from time to time—the reports of the sanitary officials contain abundant testimony of the intimate relations subsisting between cholera outbursts and specifically polluted drinking water.

Dr. Buchanan has said of some of the towns in this country examined by him, in which extensive sanitary improvements had been undertaken, "cholera epidemics appear to have been rendered practically harmless;" one of the most important of the sanitary improvements being the introduction of an abundant supply of pure water. The manner in which water becomes infected is the same for cholera as for enteric fever. In both cases the poison of the disease is contained in the evacuations of the patient, and these if discharged into defective privies, cesspools, or sewers, may find their way into the soil and underground sources of water-supply, or may be carried into the streams and rivers from which the population derives its drinking water. In India, the filthy habits of the natives cause a gross and persistent pollution with fæcal matters of the drinking water in the tanks, from which so large a population obtain their entire supply. There is not sufficient evidence to clearly decide whether cholera evacuations are infectious from the moment of their discharge, or must undergo some putrefactive or fermentative changes subsequent to their escape from the body, before they can develop their contagious properties.

Ague, malarious fevers.—In malarious districts it is not generally possible to separate the influence of polluted drinking water, as provocative of the disease, from the other conditions, possibly equally potent, under which the population exists. There can be no doubt, however, of the authenticity of the many instances recorded where ague and remittent or intermittent fevers were traced to the drinking of water derived from marshes, or collected in malarious districts; all other conditions known to be provocative of such disorders being absent. These malarious waters have always been found to contain an excessive quantity of vegetable matter; but its exact nature or condition, as regards freshness or putridity, has not been ascertained. It seems certain, however, that the poison of malaria, whether it be a specific microbe or bacillus or not, exists as such in nature under conditions of temperature, moisture, soil, and vegetation, suitable to its growth; and that its introduction into the human organism is accidental, and not necessary to any phase of its existence. It differs therefore from the poisons of the true specific diseases, which must be derived from a pre-existing case, and which, as far as we know, grow and multiply chiefly in the human body. Malarious fevers may arise spontaneously amongst a population settled in a hitherto uninhabited district; but the true specific diseases would not so appear unless introduced from without.

Yellow fever has been traced to drinking water polluted with the discharges of people ill of the disease;

but other modes of spread are probably equally potent and more frequent.

Diphtheria is not usually propagated through the medium of drinking water, but cases favouring such a view have been recorded.

Urinary calculi were at one time supposed to arise from the use of hard water, but this view is now generally abandoned from want of any definite proof.

Goitre appears to be due, in many instances, to the water used for drinking, but the impurities in the water which favour hypertrophy of the thyroid gland in some districts, are not those found in the water of other goitrous districts. The carbonates and sulphates of lime and magnesia, which are present in the waters of some districts, and have been credited with being the cause of goitre in those districts, are not found in the waters of other districts where goitre prevails. The presence of sulphides of iron or copper in water has been regarded by some observers as the efficient cause of goitre, but not apparently with much reason. On the whole then we shall be justified in concluding, that the quality of the drinking water in districts where goitre and its allied disease cretinism exists, is only one—and perhaps not the most potent—factor out of many which, in combination, are productive of the disease. Further researches are required to elucidate this question, which is one of great interest.

Entozoa.—The embryos or eggs of the following parasites have been found in water, and may be taken into the stomach of man, when such water is used for drinking. They are:—*Tænia solium*, *Bothriocephalus latus*, *Ascaris lumbricoides* (Round worms), *Oxyuris vermicularis* (Thread worms), *Filaria sanguinis hominis*, the embryos of which are sucked from the blood by mosquitoes, and then transferred to water, *Bilharzia hæmatobia* (?), and *Distoma hepaticum* (Liver fluke of sheep). The guinea worm, *Filaria dracunculus,* penetrates into the subcutaneous cellular tissue of the legs of bathers; whilst *leeches* may fix themselves in the pharynx and cause much hæmorrhage.

Metallic poisoning may be caused by pollution of drinking water with refuse from trades, and drainage from metalliferous mines, or from absorption by water of the metals used in the construction of distributing pipes, tanks, and cisterns. The amounts of mercury, copper, zinc, or arsenic, which must be present in the water to give rise to symptoms of poisoning, have not been ascertained; as regards lead, as little as $\frac{1}{10}$ grain per gallon may produce plumbism in predisposed persons. In the case of the poisoning of Louis Philippe's family at Claremont, $\frac{7}{10}$ grain of lead was found in each gallon of water.

Examination of Water for Sanitary Purposes.

It will be sufficient here briefly to sketch out a short scheme for the examination of water for medical and sanitary purposes. For further information on this subject reference must be made to the larger textbooks. The points to which attention should be especially directed are:—1. *Physical examination of the water;* 2. *Microscopical examination of suspended matters and sediment;* 3. *Quantitative examination of dissolved solids;* 4. *Biological examination of the water.*

Physical Examination.

1. *Colour.*—The water should be examined in a two-foot tube. Pure waters have a bluey-grey tint. A green colour indicates contamination with vegetable matter. Light brown, or yellow, is often due to the presence of sewage matters, but may be caused by peat or by salts of iron in the water.

2. *Clearness or turbidity.*—The purest waters are clear, bright, and sparkling. Polluted shallow well-waters sometimes exhibit these very qualities.

3. *Taste.*—Polluted waters often have a disagreeable taste; but as often not, if the solids are perfectly dissolved, and the water is well aerated. Non-aerated waters have a flat taste. Iron in very small quantities can be tasted, but other salts in water cannot be tasted unless they are present in large proportions.

4. *Smell.*—The water should be put in a flask and gently warmed. Sulphuretted hydrogen, and the gases indicative of fermentation or putrefaction may thus be recognised. A suspected water may be put in a stoppered flask and kept in a warm place for a few days, to observe any changes that may arise, such as turbidity from commencing putrefaction.

The physical characteristics of a water, though by no means conclusive in themselves, should not be neglected, as they give valuable corroborative evidence to the methods of examination presently to be described.

Microscopical examination of the sediment.—The object of this examination, in a majority of cases, is to determine whether the water has been polluted with sewage or domestic refuse. Fibres of cotton, wool, or linen, starch cells, macerated paper, human hairs, yellow globular masses, and striped muscular fibre (undigested meat) with squamous epithelium cells are all indicative of contamination of the water with human refuse, and most probably with sewage. Amongst these matters, and feeding on them, will probably be found living organisms of a low type, such as bacteria (micrococci, bacilli, and vibriones), amœbæ, and infusoria. These organisms are not in themselves dangerous, but they indicate the presence of matters—chiefly organic—upon which they feed, and amongst them may be those disease-producing organisms which so often find their way into sewage (figs. 4—8).

Pollution of water with vegetable matters may be recognised by the presence of vegetable cellular tissue, fungi and moulds, algæ, diatoms, desmids and confervæ (figs. 9—12). Amongst decaying vegetable matter will be found an abundance of microscopic living organisms, including bacteria, amœbæ, euglenæ, infusoria (vorticellæ, paramæcia, coleps, stentor, oxytricha, &c.), anguillulæ or water worms, rotifera or wheel animalcules, entomostraca (daphnia pulex (water flea) and cyclops quadricornis), amphipoda, isopoda, and tardigrada (water bears), the larvæ of the water gnat, and the pupa forms of other insects, besides many others.

It may be stated that the lowest organisms like bacteria, when present in large numbers, indicate that putrefactive changes are taking place, and generally that the presence of bacteria, amœbæ, and infusoria, must be regarded with great suspicion, because the polluting materials with which they are associated are more likely to be dangerous than the vegetable masses from ditches and ponds, amongst which the higher organisms are usually found.

The sewage-fungus (Beggiatoa Alba) is found in

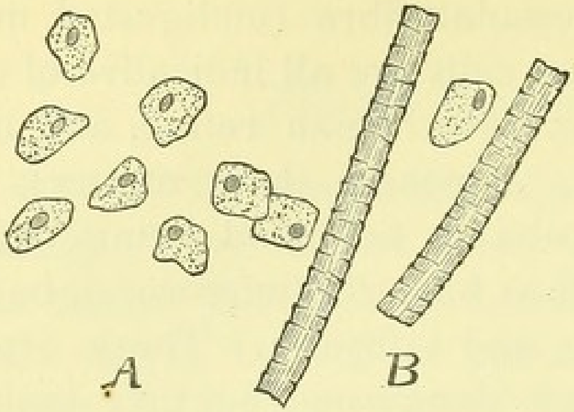

FIG. 4.

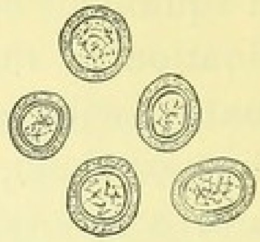

FIG. 5.

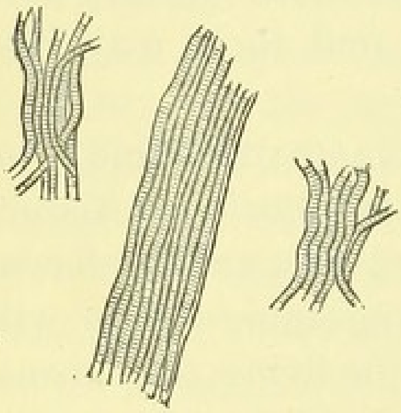

FIG. 6.

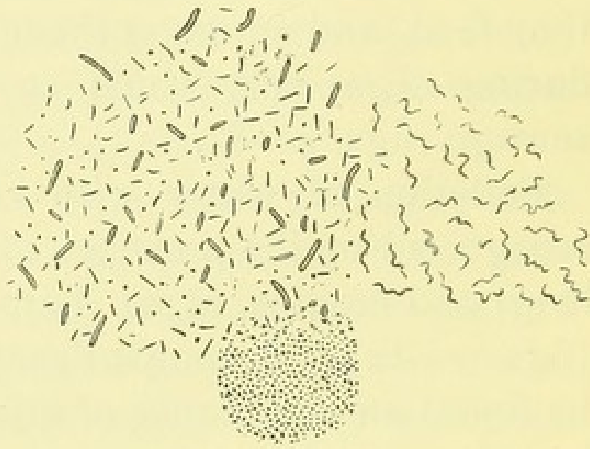

FIG. 7.

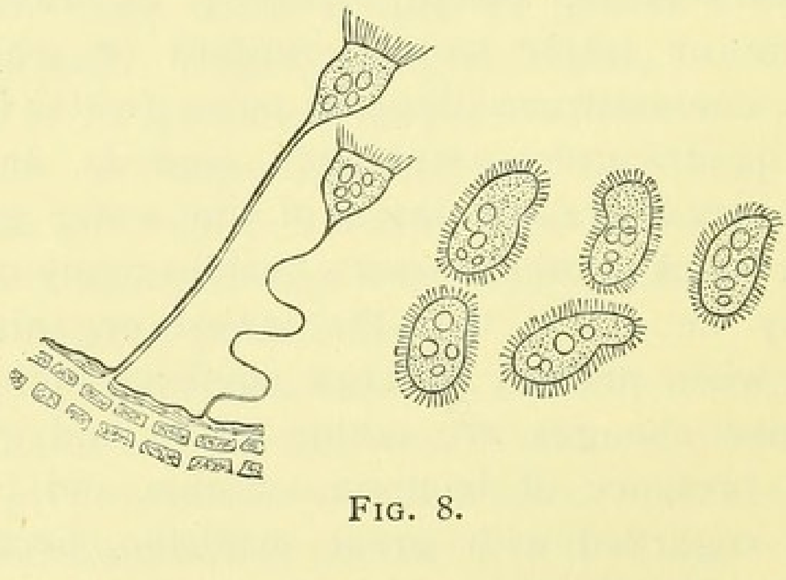

FIG. 8.

SEDIMENT OF A POLLUTED WATER (× ABOUT 200 DIAMETERS).

FIG. 4.—A. Epithelial cells. B. Hairs (human).
FIG. 5.—Ova of Tape-Worm (Tænia solium).
FIG. 6.—Voluntary muscular fibres.
FIG. 7.—Bacteria (Micrococci, Bacilli, Spirilla).
FIG. 8.—Ciliated Infusoria (Vorticella, Paramecium).

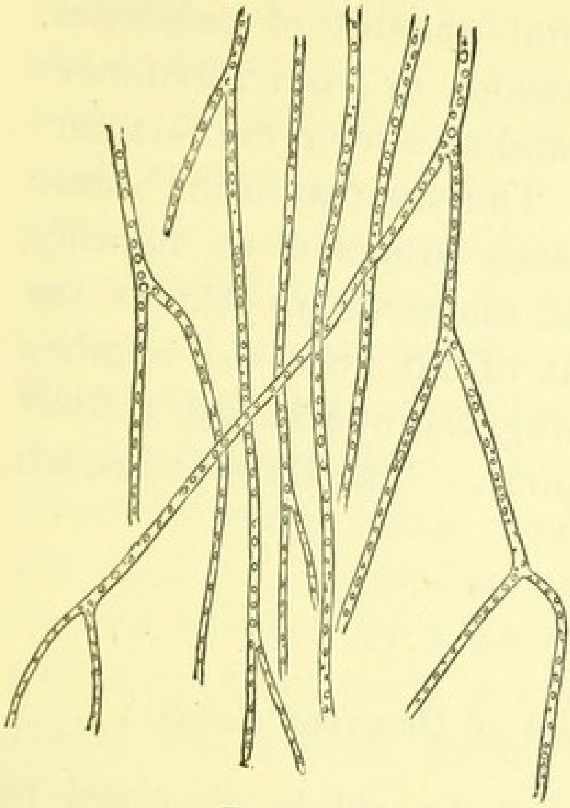

FIG. 9.

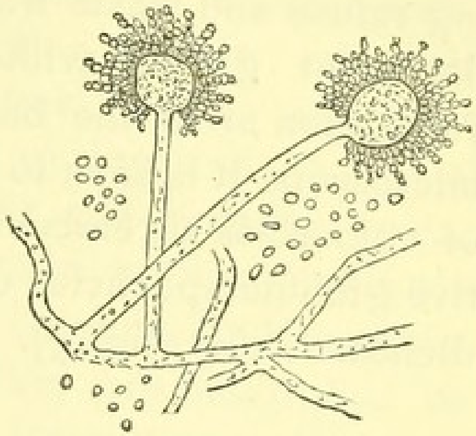

FIG. 10.

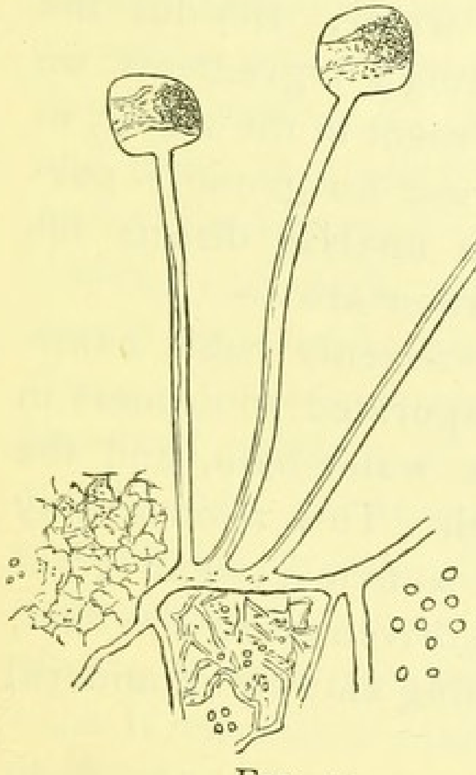

FIG. 11.

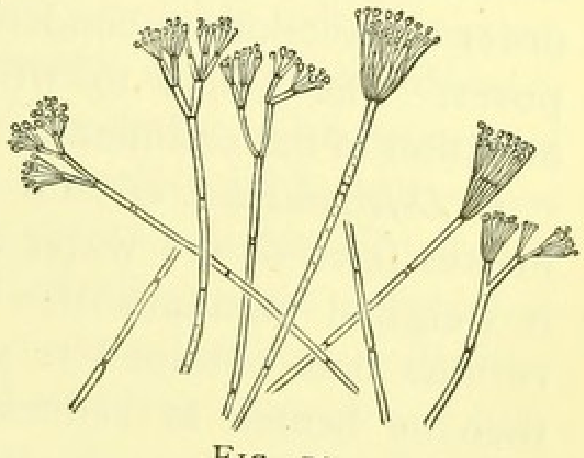

FIG. 12.

FUNGI AND MOULDS.

FIG. 9.—Beggiatoa Alba (Sewage Fungus) × about 200 diameters.
FIG. 10.—Aspergillus Glaucus × about 150 diameters.
FIG. 11.—Mucor Mucedo × about 80 diameters.
FIG. 12.—Penicillium Glaucum × about 200 diameters.

waters containing an abnormal amount of sulphates, derived either directly from sewage, or from substances used in precipitating sewage, and also from manufacturing refuse and waste waters. The fungus forms dense flocculent greyish-white masses attached to floating vegetation or to the banks of the stream. Under the microscope it is seen to consist of an immense number of colourless threads containing bright strongly refractive globular particles of sulphur. The threads branch dichotomously (fig. 9).

Quantitative Examination of Dissolved Solids.

A qualitative examination of the solids dissolved in water is not sufficient to enable us to arrive at any conclusion as to the purity of a water. Besides the different kinds of polluting or foreign ingredients, we must know the amounts of each present in the water, in order to sanction or condemn its use for potable purposes. The points to which the analyst directs his attention in the examination of a water are:—

1. *Determination of total solids.*—Seventy cubic centimetres (c.c.) of the water are evaporated to dryness in a weighed platinum dish over a water-bath, and the residue thus obtained is weighed. This residue may then be heated to redness over a flame, when volatile salts and organic matters are driven off by the heat, the residue which remains consisting entirely of mineral matters.

The French metric system is universally used in quantitative analysis, on account of the greater facilities for calculation which it offers over any English system of weights or measures; and results are usually expressed as parts per 100,000, or as parts per million, which is the same thing as milligrammes per litre—a litre of water consisting of 1000 cubic centimetres, and each cubic centimetre of pure water at 4° C. weighing one gramme (= 1000 milligrammes). Results are also sometimes expressed as grains per gallon; and as a gallon of water weighs 70,000 grains, and 70 c.c. of water weigh 70,000 milligrammes, the quantity 70 c.c. is a miniature gallon; and results in milligrammes obtained by using 70 c.c. may also be expressed as grains per gallon. If grains per gallon are multiplied by 10, and divided by 7, parts per 100,000 are obtained; and conversely, parts per 100,000 may be altered into grains per gallon by multiplying by 7 and dividing by 10.

*Chlorine.**—The determination of chlorine is very important, as an excessive amount of sodic chloride usually co-exists with contamination of the water by sewage. Sewage derives its chlorine from the urine it contains; and sodic chloride being a very soluble salt is not removed by filtration even through a very considerable thickness of earth. 70 c.c. of the water to be examined should be placed in a white porcelain dish, and a few drops of yellow chromate of potash solution added. A standard solution of nitrate of silver (see Appendix) should then be dropped in from a burette, until—the chlorine being all precipitated as silver chloride—a reddish colour of silver chromate is just obtained. The nitrate of silver solution is made of such strength that 1 c.c. is capable of exactly neutralising one milligramme of chlorine. Excessive amounts of chlorine are also found in brackish waters from wells near the sea, and in cer-

* For the preparation of the Standard Solutions, see Appendix.

tain deep well-waters; so that the presence of excess of chlorine must not be taken as absolute proof of sewage contamination; as a confirmatory test it is of great value.

Nitrates and Nitrites.—These are the oxidised residues of organic matters, possibly derived from an animal source (sewage). Their determination is therefore a point of the greatest importance, for they indicate, either a pollution of the water at some remote period with possibly dangerous ingredients, or the contamination of the water at the present time with partially or completely purified sewage. They are found, often in considerable quantities, in deep well or spring waters, and in this case merely indicate the complete purification which the water has undergone in its passage from the surface to the subterranean reservoirs. In the case of shallow well-waters, nitrates and nitrites, if found in association with excess of chlorine and ammonia, indicate soakage of sewage or animal refuse into the well, more or less purified by its passage through the intervening layers of earth. At any time, however, the purifying power of the filtering earth may be exceeded or overcome, and then the liquid filth may pass into the well with its dangerous ingredients unchanged and unpurified. Nitrates and nitrites are not present in raw sewage; but they are found in polluted streams and watercourses, where a certain amount of oxidation is always in progress, and in the effluent subsoil waters from manured or sewaged land. They exist as nitrates and nitrites of lime, soda, potash, etc.

The simplest method of estimating the amount of nitrates, is to evaporate 10 c.c. of the water in a small platinum dish to dryness. To the residue add 3 c.c. of a solution of sulphuric acid and phenol (see Appendix), and two drops of pure hydrochloric acid, and then warm the dish for 3 minutes over the water bath. Pour the contents into a Nessler glass, and neutralise with caustic potash solution until effervescence ceases; then fill up with distilled water to the 50 c.c. mark, and compare the depth of the yellow colour produced with that of a test solution, containing one milligramme of nitrate of potash in each cubic centimetre, to which the same reagents have been added. This process of comparison by depth of colouration is known as "Nesslerising." To express in terms of nitrogen as nitrates, the result must be multiplied by 0·14.

Where there is a suspicion of sewage pollution a qualitative examination should be made for *phosphates*. This is readily done by adding to some of the water (concentrated if necessary) some molybdate of ammonium and dilute nitric acid. On boiling, a yellow colour appears if phosphates are present.

Ammonia.—The urea of the urine by a process of fermentative decomposition rapidly becomes carbonate of ammonia in sewage. Ammonia will therefore be found in all sewage polluted waters, unless the sewage has been filtered through a sufficient thickness of soil to convert the ammonia by oxidation into nitrates and nitrites. A few pure deep well-waters from the chalk and greensand are found to contain excess of ammonia; but they are remarkably free from organic matters. On the other hand sewage polluted shallow well-waters, which contain excess of ammonia, contain also an excessive amount of organic matters.

To estimate ammonia, half a litre of the water should be distilled in a boiling flask connected with a Graham's condenser, until 150 c.c. of distillate have been obtained. The first 50 c.c. contain usually three-quarters of the entire amount of saline and free ammonia thus driven off; so that if the quantity of ammonia in the first 50 c.c. is estimated, it is only necessary to add a third of this amount to obtain the whole quantity present in half a litre of the water; but the method of estimating the ammonia in each 50 c.c. of distillate, as it comes over, is to be recommended. To each 50 c.c. of distillate 2 c.c. of Nessler's solution are added, and the yellow colouration produced is compared with that obtained from a measured quantity of a standard solution of ammonium chloride, each c.c. of which contains 0·01 milligramme of ammonia. Nessler reagent forms with ammonia iodide of tetramercurammonium.

Organic matter.—The quantitative determination of organic matters in water is the most important, and at the same time the most difficult procedure in water analysis. If a water is quite free from any trace of organic matter, and the inorganic salts are not of a nature injurious to health, the water may be pronounced pure and wholesome. Organic matters derived from an animal source are dangerous as well as disgusting; the slightest trace of such matters in a water should suffice to condemn it. Organic matters derived from the vegetable world, though often quite harmless, as when they exist in the form of peat, should not be disregarded, and their presence in considerable quantity should ensure the rejection of the water for drinking purposes.

The distinction between animal and vegetable organic matters in a water is often only made with difficulty, if at all. Generally it may be said, that when excess of organic matter in a water co-exists with excessive total solids, chlorine, and ammonia, the source of pollution is animal filth or sewage. When, on the other hand, excessive organic matter is not accompanied by excessive total solids, chlorine, and ammonia, the source of pollution is probably vegetable; and this diagnosis may be confirmed by the results of physical examination of the water, and by microscopic examination of the suspended matters and sediment.

The methods of estimating the amount of organic matters in a water only give approximate results; they are not capable of determining the total amount of such matters in a water. This is a great drawback, as the results of one process, though perfectly comparable in themselves, cannot be compared with the results of another process. There are three processes usually resorted to by water analysts; (*a*) the *albuminoid ammonia process* (Wanklyn's); (*b*) the *permanganate process;* (*c*) the *organic carbon and organic nitrogen process* (Frankland's).

The *albuminoid ammonia* process is simple and effective. To the water remaining in the flask, after the distillation of 150 c.c. for the estimation of ammonia (free and saline), 50 c.c. of a strongly alkaline solution of permanganate of potassium is added, and the distillation is then continued, each 50 c.c. of distillate having its ammonia estimated until no more comes over. The ammonia is the result of the action of the caustic permanganate solution at a boiling temperature on the nitrogenous organic matters (or some of them) in the water. Urea is not acted on by the solution; but this substance is not found in sewage unless very fresh, and is never found in sewage polluted water. It is obvious that all the free or saline ammonia must be driven off by distillation before commencing the process for albuminoid ammonia. Ammonia and albuminoid ammonia are usually expressed as milligrammes per litre, or parts per million.

By the *permanganate process*, the oxidisable matters in water are determined in terms of the oxygen required for their oxidation. These matters include oxidisable organic matters, nitrites, ferrous salts, and sulphuretted hydrogen. Sulphuretted hydrogen can be dispelled by heating the water, and the salts of iron can be at once recognised by the chalybeate taste of the water; usually they may be disregarded. To estimate, therefore, the oxidisable organic matters and nitrites, 250 c.c. of the water are taken, and 3 c.c. of sulphuric acid added; the permanganate of potassium solution, of a strength capable of yielding 0·1 milligramme of oxygen for each c.c., is dropped in from a burette until a pink colour is established. The flask or beaker is then warmed until a temperature of 140° F. is reached, and more permanganate solution is dropped in until the pink colour is permanent for a few (10 or 15) minutes. The number of milligrammes of oxygen required for the oxidation of oxidisable matters can thus be determined from the number of c.c's. of permanganate solution used.

If the acidified water is boiled for 20 minutes before adding the permanganate solution, the nitrous acid is driven off, and on cooling to 140° F., the oxidisable organic matter, in terms of oxygen required for its oxidation, may be determined. The nitrous acid, in terms of oxygen required for its oxidation, may be determined by calculation of the difference between the results of the two preceding processes.

The permanganate process is simple and convenient, but the results obtained by it can only approximately represent the total amount of organic matters in any sample of water, for we do not know what proportion the oxidisable organic matters bear to the total organic matters in the water, that is to say, we do not know how much of the organic matter in any sample of water is oxidisable by an acid permanganate of potassium solution, and how much is not. Nitrous acid is believed to be the first stage in the nitrification of organic matters and ammonia, and to indicate, therefore, incomplete oxidation and possible danger.

In the *Frankland process*, the water is evaporated, and the residue burnt with oxide of copper. Nitrogen and carbonic acid gases are set free from the organic matters, and their volumes respectively measured. This process is extremely difficult and complex, and—except in the hands of the most expert—is now generally held to give no more trustworthy results than the albuminoid ammonia process. In fact it has been asserted that the error of experiment is often greater than the total quantity of the gases to be measured. It is desirable, however, to have some knowledge of the manner in which the results are stated, chiefly because the analyses in the Reports of the Rivers Pollution Commission—the most interesting and exhaustive reports on water supplies ever compiled—were conducted by this process (see p. 38).

The Commissioners stated that good drinking water should not contain more than 0·2 part of organic carbon, and 0·02 part of organic nitrogen per 100,000 parts of the water. The ratio of organic carbon to organic nitrogen is especially important—a high ratio indicating a vegetable origin of the organic matter, whilst a low ratio indicates an animal or sewage origin.

In sewage the ratio $\frac{\text{organic carbon}}{\text{organic nitrogen}}$ is less than $\frac{3}{1}$, whilst in pure peaty waters it may be $\frac{20}{1}$. The ratio for drinking water should not be less than $\frac{6}{1}$ or $\frac{7}{1}$. In sewage of average strength the organic carbon amounts to 4 parts per 100,000, and the organic nitrogen to 2 parts per 100,000, the ratio being $\frac{2}{1}$. The "total combined nitrogen" which forms one column of the table of analyses on page 38 is obtained by adding together organic nitrogen, nitrogen as nitrates and nitrites, and nitrogen as ammonia, the result being expressed as parts per 100,000.

The column of "previous sewage or animal contamination," which is given in the analytical results of the Rivers Pollution Commissioners has been omitted from the table on p. 38, as being not only a useless but also a misleading superfluity. This is plainly apparent from its construction which is as follows:—the sum of the quantities of nitrogen present as nitrates, nitrites, and ammonia, per 100,000 parts is multiplied by 10,000, and 320 (for the ammonia present in rain) is subtracted from the result, which represents the mineral residue of the previous sewage or animal contamination of the water in terms of London sewage, assumed to contain 10 parts of total combined nitrogen (chiefly organic nitrogen) per 100,000 parts. It will be readily understood that by such a calculation, some of the purest spring and deep well-waters which are rich in nitrates or ammonia, exhibit astonishing numbers indicative of the grossest previous sewage contamination—contamination to which they have in fact never been subject.

Hardness.—Hardness may be due to salts of lime or magnesia, to volatile (CO_2) or fixed acid. To estimate the total hardness, 70 c.c. of the water are placed in a stoppered bottle, and soap solution is run in until, on shaking, a lather is formed which is permanent for five minutes. The soap solution is made of such a strength that 1 c.c. is capable of exactly neutralising 1 milligramme of carbonate of lime. The number of c.c. of soap solution required to form a lather in the 70 c.c. of water, is the number of milligrammes of carbonate of lime in the 70 c.c.; or, what we have seen to be the same thing, the number of grains per gallon, after deducting 1 c.c. which is required to form a lather in 70 c.c. of distilled water containing no lime. If the same process is gone through with water which has been boiled for some time, the permanent hardness can be estimated, and the temporary hardness by deducting this result from the total hardness. The hardness due to magnesian salts can be estimated separately with the soap solution after precipitating all the lime salts with oxalate of ammonia. Degrees of hardness on Clark's scale correspond with the number of grains per gallon of the lime and other salts, producing hardness.

Metals.—To some of the water in a porcelain dish, a drop of sulphide of ammonium should be added. If iron, lead, or copper, are present, even in very slight traces, a dark colouration will be imparted to the water. If it is iron, the addition of a few drops of hydrochloric acid will cause the colour to disappear; if lead or copper are present, the colour remains. The presence of even a trace of either of these two metals in a water should be sufficient to condemn it. Iron is harmless, and may be tolerated in a water on the score of health. To detect arsenic in a water, large quantities must be evaporated down, and the residue put into a Marsh's apparatus.

It may be as well here to give a few samples of analytical results as usually expressed by chemists using the Wanklyn process.

	Grains per Gallon			Parts per Million		Degrees
	Total Solid Residue	Chlorine	Nitrogen as Nitrates and Nitrites	Saline Ammonia	Albuminoid Ammonia	Hardness
New River Company, filtered.	17·6	1·2	0·15	0·02	0·04	15
Unfiltered Thames water at Hampton.	32·0	1·8	0·222	0·04	0·28	16
Polluted shallow well-water.	96·5	10·5	3·50	6·00	0·31	42
Sewage effluent from precipitation works.	80·5	11·2	—	18·5	3·86	23

The quantities are given as grains per gallon, with the exception of the ammonias which are expressed as parts per million. It may be stated generally, that the albuminoid ammonia should not exceed 0·08 parts per million in a good drinking water. In the unfiltered Thames water, the excess of albuminoid ammonia without any excess of free ammonia or chlorine, points to vegetable contamination. The pollution of the shallow well-water is evidently caused by sewage, as shown by excess of chlorine, nitrogen as nitrates, and free ammonia.

Biological Examination.

Inasmuch as the chemical methods of analysis can only determine the presence and amount of organic matters in water, and cannot determine their quality, nor separate living and possibly actively dangerous organisms from dead and inactive matter, it has been thought by many that those methods of cultivating fungi and bacteria and their spores on sterilised nutrient media, which were first introduced by Koch, would afford valuable evidence of the possibly dangerous qualities of a water, and might come in time to supersede chemical analysis altogether.

Such has not been found to be the case, and the reason is not far to seek. In the first place the specific micro-organisms of those diseases which are occasionally spread by polluted water, have not yet been isolated and identified. If there be such organisms, they cannot be separated from the crowd of harmless species which are found in greater or less abundance in all natural waters. There is therefore at present a complete failure to identify the actual agents of disease. The finding of a greater or less number of non-pathogenic bacteria or fungi in a water simply gives confirmatory evidence—if any such was wanted—of the presence of a larger or smaller amount of organic matter, ammonia, nitrates, or phosphates, in the water, which form a suitable pabulum for bacterial germs.

Chemically pure waters are found to contain very few bacteria or fungi, whilst impure waters often swarm with them. They increase in numbers if water is stored for any length of time—increasing at the expense of the ammonia and other sources of energy in the water. They are largely removed by filtration through clean sand and good domestic filters, just as other impurities are, but perhaps to a greater extent.

On the whole then we must conclude that the biological test is valuable only for the confirmation it gives of the results of chemical analysis, and not because it is capable of throwing any further light on the dangerous or harmless qualities of a water. Under ordinary natural conditions, waters found to be chemically pure are not capable of causing disease; and all waters, with but very few exceptions, which have caused disease have been found by chemical examination to be polluted—often grossly polluted. Distilled water infinitesimally polluted with a few grains of enteric fever stool, is not a water contaminated under ordinary natural conditions; and it would probably be passed as pure and wholesome by the biologist, who had counted the number of bacteria in a cubic centimetre, as well as by the chemist who failed to find evidence of organic pollution sufficient to condemn it.

As usually carried out the biological examination is conducted as follows:—A measured quantity of the water—1 c.c. or a fraction of 1 c.c.—is mixed with a test-tube-full of liquefied sterilised nutrient gelatine, which is then poured on a glass plate and placed under a bell-jar, with suitable precautions to prevent the entrance of atmospheric spores. After a few days the germs or spores are found to have developed into recognisable colonies, which may be counted and differentiated by their colour, their mode of growth, the liquefaction they produce in the gelatine, and other characteristics. Under the microscope the colonies may be separated into the different varieties of bacteria, moulds, and fungi; and each colony may subsequently be submitted to cultivation in test-tubes of gelatine, agar-agar, blood serum, &c.

CHAPTER II.

THE COLLECTION, REMOVAL, AND DISPOSAL OF EXCRETAL AND OTHER REFUSE.

In any community of persons, arrangements must be made for the collection and removal of their excretal refuse (fæces and urine), of the waste waters from houses, and of the dry refuse (ashes, dust, and refuse food). In towns, the solid and liquid refuse matters from stables, cowsheds, and slaughter-houses, street sweepings, and the waste waters from works and manufactories must also be removed. Part of this refuse, viz., human fæces and dung of animals, street sweepings, ashes, dust, and refuse food, is in a solid and more or less dry condition, whilst the remainder is liquid.

In all towns the collection and removal of dung, ashes, dust, refuse food, and street sweepings is performed by mechanical labour, the various processes above mentioned being included in the term *scavenging;* whilst in some, human fæces and a certain amount of urine are also removed by this method, after being deposited in privies, cesspools, or dry closets, on what is known as the *Conservancy System.* In a large majority of the towns of this country, at the present time, human fæces with the whole of the urine are removed with the liquid refuse on what is known as the *Water-carriage System*—a system of drains and sewers for the passage of the refuse in a liquid condition to some spot outside the town.

On the efficiency with which refuse matters, and especially human excretal refuse, is removed from towns, their health largely depends. The Reports of the Health of Towns Commission and the Sewage of Towns Commission, and the Reports of the Medical Officers of the Privy Council and Local Government Board give amply sufficient evidence on this head. The health of nearly all towns in this country and abroad has very much improved, and the death-rates have been permanently lowered since the completion of works of sewerage with, however, in many instances the introduction of a better water supply.

Solid and Liquid Excreta.—An adult male, living on a mixed diet of animal and vegetable food, passes daily 4 ounces, by weight, of solid, and 50 fluid ounces of liquid excreta. The solid and liquid excreta of women and of children under twelve years are in amount considerably less, probably, on an average, not much more than one-half the above quantities. If all ages and both sexes are considered, the daily amount of excreta per head of a mixed population may be taken as 2½ ounces of fæces, and 40 ounces of urine (Parkes' *Practical Hygiene*, 7th edit.). Fresh fæces contain on the average 23·4 per cent. of dry solids, and fresh urine contains 4·2 per cent. of which rather more than half (54 per cent.) is urea.

The quantity of nitrogen voided per head in the excreta of a mixed population was calculated by the late Prof. Parkes as being 153 grains, equal to 186 grains of ammonia. The other valuable constituents of the excreta are phosphates and potash. A given weight of fæces is more valuable than the same weight of urine, in the proportion of about 10 to 6; but the weight of urine passed (in a mixed population) is nine or ten times as great as that of the fæces, consequently the total urine is worth about six times as much as the total fæces. The total Nitrogen voided annually by an individual of a mixed population is taken as being equivalent to 10 ℔ of ammonia, worth 6*s*. 8*d*. Higher values have been given by various authorities, but it is better to take the lower estimated value, especially as it was stated by the late Dr. Voelcker that nitrogenous organic matters (in which form the nitrogen of sewage principally exists) is worth considerably less than ready made ammoniacal salts. The value of potash is 2*d*. per ℔, and of phosphate of lime 1*d*. per ℔, but the amounts of these constituents in the excreta are very small.

The estimated or theoretical money value, then, of the excretal refuse of an individual of a mixed population for one year, may be taken as being from 6*s*. 8*d*. to 7*s*. It is very evident that it must be impossible to realize practically any such value, because it is impossible to collect the whole of the urine and fæces pure, *i.e.*, unmixed with other substances, which greatly detract from the value because they are agriculturally worthless.

Fæces and urine, especially when mixed, as in cesspools, privies, and sewers, rapidly undergo putrefactive changes, giving rise to the formation of fœtid gases (organic vapours, ammonium sulphide, etc.). The urea ($CO(NH_2)_2$) of the urine decomposes, giving rise to carbonate of ammonia; and so rapid is this change, that it is probable that even in the best sewered town, all the urea of the urine in the sewage has been converted into ammonia before the arrival of the sewage at the outfall.

House waste waters.—In these are included the waste waters from kitchens, which are highly charged with decomposable organic matters and grease, and slop-waters containing urine, soap, the dirt from the surface of the body and from clothes. These waste waters, when mixed with the liquid refuse or drainage of stables, cowsheds, and slaughter-houses, with the washings from the street surfaces, with the urine from public urinals, and with the waste liquors from manufactories, form the sewage of the non-water-closeted or midden towns. The drainage from stables is very rich in urine (one horse excretes about 15 times as much urine as an adult man); and the waste liquors from manufactories are often excessively foul.*

It is not surprising then to find that such sewage is but little less foul than that of water-closeted towns, which contains the solid human excreta as well. The putrescible organic matter in suspension is greater in midden than in water-closet sewage, whilst the organic matter in solution is but slightly less in the former than in the latter. The Rivers Pollution Commissioners stated in their First Report, that "for agricultural purposes, 10 tons of average water-closet sewage, may, in round numbers, be taken to be equal to 12 tons of average privy sewage," *i.e.*, sewage of privy towns, where human fæcal matters are kept out of the sewers. Such being the case, it is necessary to bear in mind, that in towns where there are middens or some form of dry closet for the collection of fæcal matters, there is also a liquid sewage to be conveyed away from the houses by drains and from the town by sewers, which is too impure to be admitted into a stream, and which must therefore be purified before being so discharged.

* The waste liquor from flannel washing is said to contain twenty times more valuable manurial constituents than London sewage, *Rivers Pollution Commission*, 3rd Report.

Conservancy Systems.

Middens.—The system which formerly prevailed in many towns in this country—where there was any system at all—was that of privies, midden-pits, and cesspools, often open to the air and unprotected from rain, and situated in the yards and areas about houses. These receptacles were generally mere holes dug in the ground; and their contents overflowed, saturating the air with noxious effluvia, or percolated into the soil around the houses, and poisoned the water in the neighbouring wells.*

At the present time, in those towns which still retain conservancy systems, the middens are required to be constructed according to certain definite rules. The model bye-laws of the Local Government Board with regard to the construction and management of privies and middens require that:—the privy must be at least 6 feet away from any dwelling, and 40 or 50 feet away from any well, spring, or stream; means of access must be provided for the scavenger, so that the filth need not be carried through a dwelling; the privy must be roofed to keep out rain, and provided with ventilating openings as near the top as practicable; that part of the floor of the privy which is not under the seat, must be not less than 6 inches above the level of the adjoining ground, must be flagged or paved with hard tiles, and must have an inclination towards the door of the privy of half an inch to the foot; the capacity of the receptacle under the seat of the privy must not exceed 8 cubic feet—a weekly removal is then necessary; the floor of this receptacle must be in every part at least 3

* See Corfield's *Treatment and Utilisation of Sewage*, 3rd edition.

inches above the level of the adjoining ground; the sides and floor of this receptacle must be constructed of impermeable materials—they may be flagged or asphalted, or constructed of 9-inch brickwork rendered in cement; the seat must be hinged, or other means of access to the contents of the privy must be provided; and the receptacle must not communicate with any drain or sewer.

With middens constructed and managed according to these rules, there would be no danger of percolation of liquid filth into the soil around houses and in the neighbourhood of wells; and there would not be much pollution of the air from the excreta—except during removal—if their dryness was ensured by the proper application to them of ashes and cinders. The success of the system depends to a large extent on efficient inspection by the nuisance inspector, and on proper scavenging arrangements.

Cesspools.—These receptacles for filth are so evidently undesirable in the neighbourhood of houses, that it is the practice now in nearly all towns to fill them in and provide more suitable means for the collection of excreta. Until the repeal, in 1815, of the law which prohibited the passage of sewage from houses into the sewers, nearly every large house in a town had a cesspool on the premises, often of enormous size and situated in the basement. When, in the year 1847, it became compulsory to drain houses into sewers, many of these cesspools were filled up or otherwise abolished; but many of them escaped observation, and to the present day it is no unusual thing to find one or more cesspools in the basements of town houses, of whose existence the owners or occupiers are profoundly ignorant.

In country districts where there are no sewers, cesspools are still largely used for the reception of all the house refuse. If dug in a porous soil, such as gravel or chalk, they are too frequently constructed to allow all the liquid filth to percolate through their walls into the soil, with the almost certain danger of polluting wells, springs, and other sources of underground water supply. When the liquids escape thus easily, the cesspool but very rarely requires emptying, and this fact constitutes the *raison d'être* of the porous cesspool.

The model bye-laws of the Local Government Board require that the cesspool must be at least 50 feet away from a dwelling, and 60 to 80 feet distant from a well, spring, or stream. It must have no communication with a drain or sewer (in sewered districts), its walls and floor must be constructed of good brickwork in cement, rendered inside with cement, and with a backing of at least 9 inches of well puddled clay around and beneath the brickwork. The top of the cesspool must be arched over and means of ventilation provided.

Constructed in accordance with these rules, the possible dangers of cesspools are reduced to a minimum. The principle, however, which is bad, remains the same: for it is not desirable to retain in any receptacle, however well constructed, a large collection of solid and liquid excretal refuse, there to undergo putrefaction with the formation of offensive gases.

In this country cesspools are generally emptied by hand labour—a disgusting and dangerous task, or by pumping into a night-soil cart. On the continent, and especially in Paris—where nearly every house has its "fosse permanente" in the courtyard—the cesspools are emptied by pneumatic pressure. A flexible tube, connected with a tub or "tonneau" exhausted of air by an air-pump, is thrust down to the bottom of the cesspool. On turning a valve the pressure of the atmosphere forces the contents up into the tonneau. This method is said not to give rise to any nuisance comparable with that due to emptying the cesspool by hand labour.

The Pail System.—In this system the excreta are re-

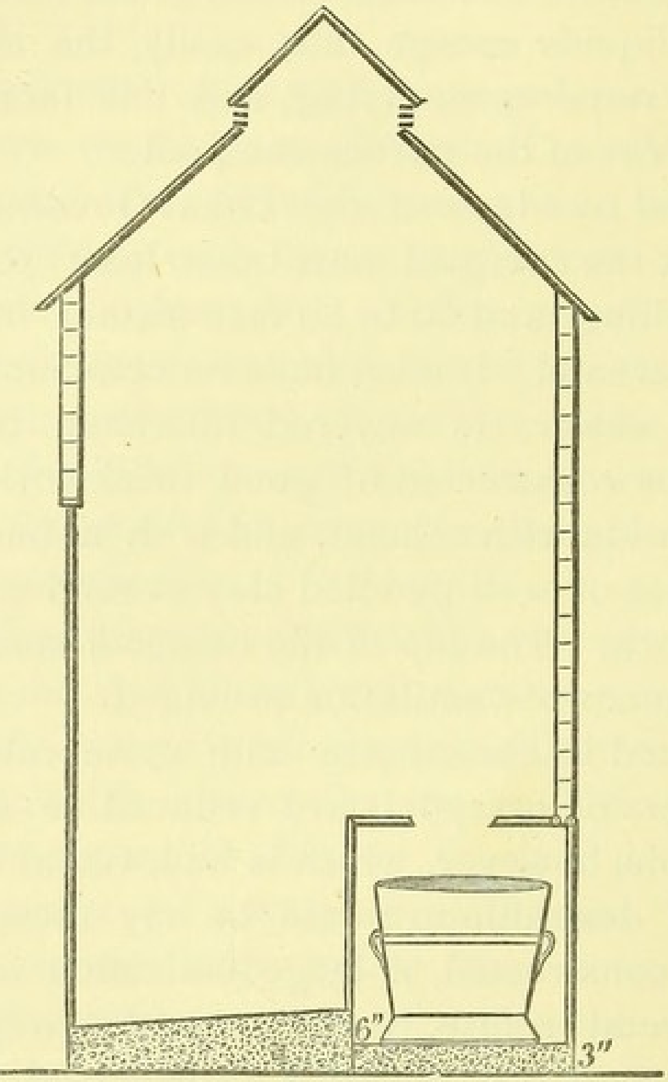

FIG. 13.—Privy constructed for Pail System.

ceived into movable receptacles, such as pails and tubs. Removal is thereby greatly facilitated, and there is no pollution of the air, from disturbance of contents, as there always must be when the contents of middens are taken away. In some towns iron pails are used, in others tarred oak pails. The capacity of the pail should not be greater than 2 cubic feet. Both kinds should be provided with a close-fitting lid, to be adjusted before removal of the pail by the scavenger.

The structure of the closet (fig. 13) need only be very simple; it should be well roofed and louvred for ventilation, its floor being raised above the level of the ground adjoining and flagged, and the pail placed under the seat. The seat may be hinged, to ensure a more complete covering of the excreta with cinders and ashes, when these are used, and to allow of the removal of the pail; or the back wall of the closet may be provided with a door to effect the latter purpose. The pail should be removed at not longer intervals than once a week, and a clean one substituted for it.

It is very important, from a sanitary point of view, that the pail contents should be kept as dry as possible; and for this object the house ashes and cinders should be thrown into the pail, either by a scoop after each use of the closet, or by a mechanical arrangement (to be described under earth-closets) above the pail, which sifts the cinders and deposits the fine ash automatically on the pail contents. At Nottingham the pails are the receptacles for the chamber urine and solid kitchen refuse as well as for the excreta and ashes. It is perhaps convenient for the authorities to remove all house refuse in one receptacle; but if it is intended to create a saleable manure from the excretal refuse, all garbage and kitchen refuse, and even all but the very finest ash (even this detracts from the value of the manure), should be kept out of the pails and removed separately. In such cases the pail contents can no longer be kept dry, and sanitary considerations must be, to a certain extent, sacrificed to ensure commercial profits.

All slops must be kept out of the pails, and must be carried away from the houses in drains with the other waste waters. In some cases separation of the urine from the fæces has been attempted. Besides introducing a complication into a system, whose chief merit perhaps is simplicity, this plan is open to the great objection of abstracting the most valuable fertilising constituents of the manure *in posse*.

In the *Goux system* an attempt is made to dry the excreta by lining a wooden tub with a layer of refuse sawdust, shoddy, tan, or other absorbent material, to which is added a little soot, charcoal, gypsum, or other deodorizer. This system is in use at Halifax, and on the whole has worked well.

Wood charcoal and a charcoal obtained from sea-weed (Stanford's) have been used instead of ashes to aid in drying the pail contents. They act as dessicators, and possibly to a certain extent as deodorizers, and have been well spoken of by the late Mr. Netten Radcliffe in his Reports to the Local Government Board.

Manufacture of Manure.—In towns situated in agricultural districts, where there is a demand for the coarser sorts of manure, the pail contents need merely be mixed with a certain portion of fine ash. But in most of the large towns where the midden or pail systems are in vogue, it is now the practice to convert the pail contents into a dry manure of a more imperishable character, which can be packed and sold at a distance. The heat required for this purpose is generated by the combustion of house cinders and refuse in a Destructor Furnace, the invention of Mr. Fryer.

The pail contents—urine and fæces without ashes—are mixed with a small portion of sulphuric acid, to fix the ammonia, in an air-tight store tank, where the thicker portion of the material settles to the bottom.

The more fluid portion of the contents of the tank is drawn off into evaporators, which are tall cast-iron cylinders, each containing near its lower end a drum-shaped heater, precisely resembling a multitubular steam boiler. These cylinders are partially filled, and the heating drums are covered with the thin liquid; steam is then introduced within the heating drums, and the liquid becomes partially concentrated.

When the contents of these cylinders have lost by evaporation the greater portion of their water, they are drawn off into a "Firman's" Dryer, into which the thick portion of the pail contents, which settled in the store tank, have also been admitted. This machine consists of a steam-jacketed horizontal cylinder, traversed by a steam-heated axis and by steam-heated revolving arms, and furnished with scrapers to keep the inner surface of the cylinder free from accumulations of dried excreta. The pail contents are admitted into the Dryer at a consistency of thin mud; after treatment they emerge as a dry powder—"poudrette"—resembling guano in appearance and quality, and estimated to be worth from £3 to £6 per ton, dependent upon analysis. The odorous gases given off during the process are all passed through the Destructor fire and burnt. From the time the liquid material enters the store tank, until the end of the process when it emerges as a dry powder, no odorous gases can escape into the outer air, and no nuisance can result.

The Dry Earth System.—This system is the invention of the late Rev. Henry Moule, and consists in the application to the excreta deposited in a pail or tub, of a certain quantity of dried and sifted earth. One and a half pounds of dry earth applied *in detail*, *i.e.*, each particular stool being covered at once with this quantity, is found to be sufficient to remove all smell and to form a compost which remains inoffensive as long as it is dry. A certain action takes place in the mixture of earth and excrement which results in the complete disintegration of the fæcal matters and paper, which after a time are found to have completely disappeared and are no longer recognisable. The compost after further drying may be used over again, and has the same action as the original dry earth. The best kinds of earth are brick earth, loamy surface soils, vegetable mould, and dry clay. Sand, gravel, and chalk, are unsuitable and inefficient.

The closet generally used with this system is almost identical with the cinder-sifting ash-closet, previously mentioned. There is a hopper or metallic receptacle above and behind the seat; and the proper amount of dry earth is shot into the pail by a simple mechanical contrivance connected with a handle, or self-acting seat arrangement. The contents of the pails must be kept as dry as possible, or fermentation results, with the disengagement of foul gases: consequently slops must on no account be thrown into them, and even chamber urine must be kept out of them, unless a considerable extra quantity of dry earth is used. The earth must be dried, before use, over a stove, and then sifted by means of a sieve, the finer portions only being used.

There can be but little doubt that the compost or manure produced by the passage of the earth even five or six times through the closet, has but little agricultural value. The British Association Sewage Committee reported of such manure that it was "no richer than good garden mould," and the late Dr. Voelcker estimated its value as only 7*s.* 6*d.* per ton. It is probable that there is some escape or evolution of nitrogen in a free state from the manure when kept; and this may partly account for its deficiency in fertilising properties. But when we reflect on the large amount of valueless earth with which the compost is diluted, and the absence from it of a large proportion of the daily urine of each individual, the reasons for its low value are not far to seek.

The Disposal of Slop-Waters.

We have already seen that the Conservancy systems do not provide for the removal of the liquid refuse, domestic or municipal, and we have seen, too, that in the so-called midden towns the liquid refuse or sewage is but little less impure than the ordinary sewage of water-closet towns. In these towns, too, there is always a certain percentage of houses provided with water-closets, so that the crude sewage is inadmissible into a river or stream, and requires to be purified in one of the ways which we shall presently speak of. A system of drains and sewers is also necessary for its removal from the town; and the principles on which such drains and sewers must be constructed do not differ from those which would be necessary if they were intended to carry water-closet sewage as well.

In small villages and isolated houses, provided with middens or some form of dry closet, the slop-waters are usually carried by a drain from a sink or yard gulley into "sumpt" holes in the garden, into an open ditch, into a cesspool, or into a stream; if into a "sumpt" hole or open ditch, there to stagnate and generate offensive gases; if into a cesspool, to percolate through its porous walls and pollute the neighbouring wells; and if into a stream, to foul it nearly as much as if they contained the solid excreta also. In some cases the slop-waters may be retained in cesspools which are rendered impermeable by brickwork set in cement and well puddled with clay outside; and they can then be utilised on garden ground by means of a pump and hose and jet. But wherever the nature of the soil—a porous soil is best—and the slope of the land will permit of it, recourse should be had to *sub-irrigation*, to purify the dirty water and utilise it to the best advantage. A very small piece of ground is required for this purpose. Mr. Rogers Field considers 4 perches of land sufficient for an ordinary cottage.

The drain conveying the slop-waters from the house should be connected with a system of 2-inch agricultural porous earthenware pipes, laid about 5 or 6 feet apart, with open joints, at a depth of about 8 to 12 inches in the soil, upon a bed of larger drain pipes divided longitudinally in half, or on terra-cotta troughs, the whole having a slight fall or inclination away from the house of 6 or 8 inches in 100 feet. The lower end of the main outlet pipe should turn up into the air to allow air to escape. This is especially necessary when the slop-waters are discharged into the sub-irrigation drains by a flush-tank.

If the soil is very porous, no under-drainage is needed; otherwise porous drain pipes must be laid at a depth of about 3 feet from the surface, with an outlet into a stream or ditch. The slop-waters escape through the porous pipes and open joints into the soil, where some of their fertilising ingredients are absorbed by the roots of the grasses and vegetables grown on the plot, and the remainder are oxidised and purified by percolation through the soil; so that the effluent water escapes, free from all polluting organic matters, into a stream or ditch, or helps to swell the volume of the subsoil water.

The chief difficulty in connection with this method is that the flow of slop-waters from a single house is so small, that the liquid penetrates but a short way along the sub-irrigation pipes, which become in time choked with deposit; and that portion of the sub-irrigation plot nearest the house receives an unduly large share of the irrigating liquid, and its cleansing properties are speedily overtaxed. This difficulty has been overcome

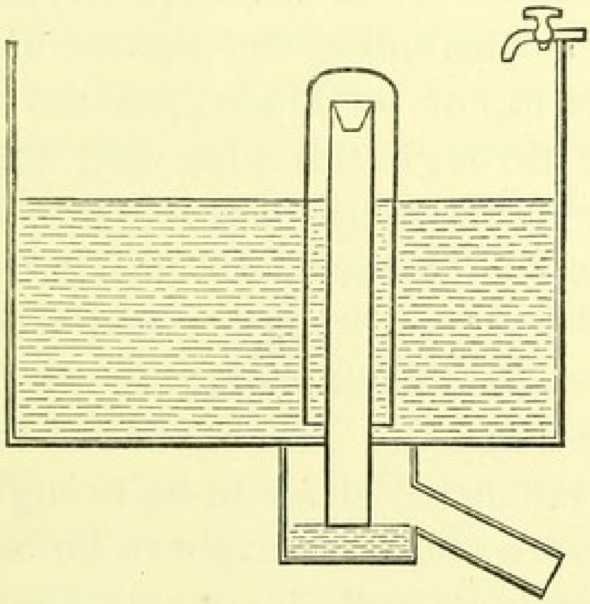

FIG. 14.—Field's Annular Siphon Flush Tank.

by interposing a flush-tank between the house pipe and the sub-irrigation pipes. The tank now in most general use for this purpose is fitted with the annular siphon arrangement, invented by Mr. Rogers Field.

In the annular siphon (fig. 14) the ascending arm of an ordinary siphon is represented by a short wide cylindrical pipe, closed at the top, which is placed over and encloses the descending arm, a longer pipe of smaller diameter. The upper end of the descending arm is open, and in Field's tank is provided with a lip projecting inwards and downwards, which serves to throw off the water, as it over-flows, into the centre of the lumen of the pipe. The lower end of the descending arm opens over a discharging trough below the body of the tank, and is trapped by the water which stands in this trough to the level of the top of a weir, over which the water flows into a pipe connected with the head of the sub-irrigation system.

Only a very small dribble of water into the tank is necessary to put the siphon into action. This takes place as follows:—Water ascends between the inner and outer pipes constituting the siphon, until it reaches the level of the top of the inner pipe, the air displaced finding an exit through this pipe and the discharging trough below. The water then trickles over the top of the inner pipe, and, thrown into its centre by the lip, falls clear of the sides, entangling and carrying air with it, which cannot pass back owing to the lower end of the pipe being trapped. This continues until the siphon is sufficiently exhausted of air to be brought into action, when the pressure of the atmosphere forces the water in the tank through it, and the whole contents are discharged.

It is not necessary to strain the slop-waters before they enter the tank, as they contain but few of the coarser suspended matters and solid particles found in water-closet sewage. The sub-irrigation drains may be connected with the flush tank by a greater or less length of water-tight drain according to circumstances. They require to be taken out of the ground and the deposit removed before they are relaid, once a year or oftener.

Comparison of Methods.

There can be no doubt that all conservancy systems proceed on a wrong principle, viz., that of keeping excremental matters within or near dwellings as long as they are not considered to be a nuisance or a danger to health. In towns the expense of scavenging is directly proportional to the frequency of removal, so that there is always an inducement to the local authority to economise at the risk of the health of the inhabitants. The costs of this kind of scavenging are high—in many towns very high—and in but very few does the sale of the refuse cover the expense of scavenging. That improved middens and pail or earth closets are a great improvement on the former disgraceful conditions which prevailed in most towns, nobody will deny; but it is difficult to justify the existence of any such systems when all the facts are known. The principal objection to them, that they only deal with a small part of the refuse of a population, and fail to deal with the sewage of a highly polluting character, we have already considered.

Movable receptacles are far better than fixed ones for the collection of excremental matters. By the use of pails, the pollution of the air caused by the removal of the contents of the middens, and the pollution of the soil—an always possible danger with middens—are avoided. Ashes should be used with the pails to ensure, as far as possible, dryness of their contents. It is better to sacrifice a possible profit on the manure than to run the risk of spreading disease by fermentation of the liquid filth. The pail system is undoubtedly the best for towns which will not enforce the adoption of water-closets. Sanitarily considered it is inferior to the earth system, in which dryness of the excrement by the addition of dry earth is part of the system. But however suitable for country houses, and for villages in this country, and for villages and stations in India, where earth of suitable quality is easily procured and dried, and the compost can be distributed over gardens and fields in the immediate vicinity, it is quite inapplicable to towns of any size, on account of the enormous quantities of earth that would have to be dried and brought into the town, the difficulties of storing the earth on the premises of houses and keeping it dry, and the still larger quantity of nearly worthless manure to be removed out of the town and finally disposed of.

The Water Carriage System.

In this system the solid excreta together with all other liquid refuse are conveyed away—borne along by flowing water—in drains and sewers from the neighbourhood of houses and towns. In many towns, before any general introduction of water-closets, sewers existed for conveying away house waste waters, stable drainage, surface and storm waters, and in some cases waste liquors from manufactories. These sewers, which were made of brick, oval or circular in section, acted also as drains; for not being constructed of impermeable materials, they admitted subsoil water, and had considerable effect in drying the soil.

It became at one time also the practice to drain off the liquid contents of privies and middens, or to carry overflow pipes from cesspools into these sewers, which, not being designed to receive excremental refuse of this description, speedily became choked with sediment. This sediment rapidly putrified, and the offensive gases given off created an abominable nuisance. It then became necessary for the sewers to be regularly cleansed, and this deposit had to be removed at great expense by hand labour. The drainage of privies and middens entered the sewers in a most foul and offensive condition, owing to the putrid state of the contents of these receptacles. Another result was that the streams and rivers, into which this sewage was permitted to pass, became highly polluted. In many towns these brick sewers still exist, and perform the double function of removing sewage and rain water, and draining the subsoil; whilst in others they are only permitted to perform their original function of carrying off rain and surface waters and draining the subsoil, impermeable pipe sewers being laid to remove the sewage of the town, on what is known as the *separate system.*

House Drainage Arrangements.

Water-closets.—A water-closet may be defined as an apparatus for the reception of excrement, which is connected with a sewer by a pipe, and in which water must be used to carry away the excrement deposited in it. It is therefore seen at once to differ in all essentials from a privy, which ought not to be connected in any way with a sewer, and in which water cannot properly be used. Water-closets may be classified under two heads:—(*a*). Those in which there is no movable apparatus for retaining water in the basin; (*b*). Those in which there is a movable apparatus. Under the first head are included *hopper* and *wash-out closets*, under the second head, *pan*, *valve*, and *plug closets*.

The *hopper closet* consists of an inverted stoneware cone, connected below with an S-shaped pipe, which retains sufficient water to prevent the free passage of air, and is known as a *siphon trap.* The old form of

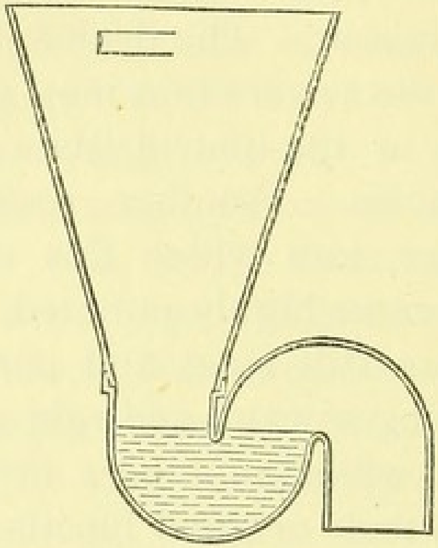

FIG. 15.—Long Hopper Water-Closet with side inlet for flushing.

hopper closet, called the *long hopper*, from the length of the cone (fig. 15), is liable to fouling of the basin, and is difficult to flush, especially where the water is admitted

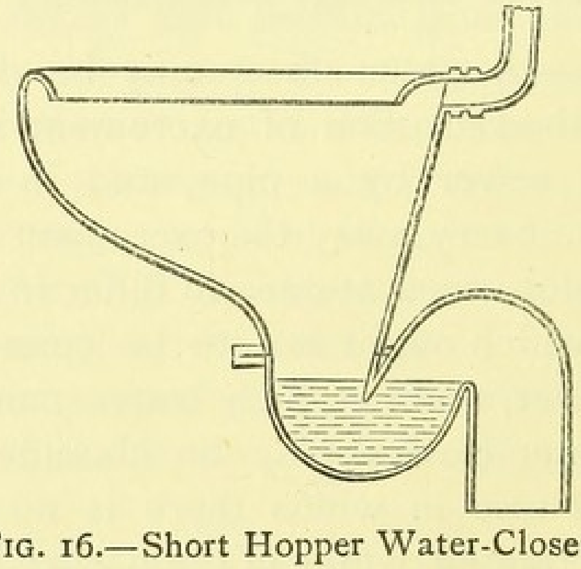

FIG. 16.—Short Hopper Water-Closet.

by a side inlet, which has the effect of causing it (the water) to whirl round and round, whereby the trap is not flushed out and excreta are left behind. The *short hopper* (fig. 16) is constructed with a shorter cone of china or stoneware, the back of the cone being made nearly vertical, so that the excrement drops into the water of the trap and not upon the sides of the basin. The short hopper, especially when constructed with a "flushing rim," by which the sides of the basin are well washed, is found, under proper management, to be easily kept clean. The closet should be flushed from a waste-preventing cistern holding not less than 2 gallons of water, placed not less than 4 feet above the seat, the service or supply-pipe being $1\frac{1}{4}$ or $1\frac{1}{2}$ inch in diameter. It is a form of closet which is now coming very largely

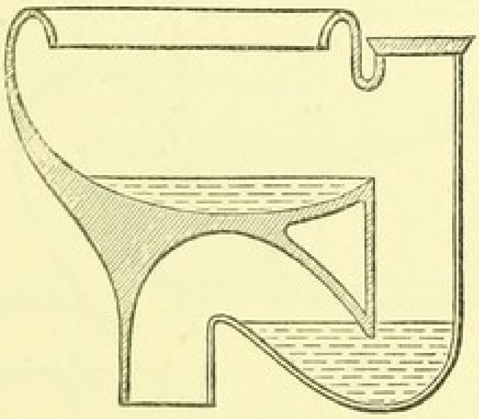

FIG. 17.—Wash-out Water-Closet.

into use, for it is simple in construction, inexpensive, has no confined air-space where foul air could accumulate, and conveys slop-waters away at once, no overflow pipe being necessary.

The *wash-out closet* (fig. 17) is constructed of stoneware or china, with the basin so shaped that a small quantity of water remains in it to receive the excreta, which are flushed out over the edge of the basin into a siphon trap below. This form of closet is difficult to flush with only 2 gallons of water, for the rush of the water from the flushing cistern is broken by the force necessary to clear out the contents of the basin, and then the water falls into the trap, but, usually, without sufficient impetus to propel the excreta through it. The basin too is very apt to become soiled by solid matters near the outlet. The basin—as in the case of every closet basin—should be provided with a flushing rim.

The *Dececo closet* (fig. 18), the invention of Colonel Waring, is similar to the short hopper closet, but is designed to retain a larger quantity of water in the basin. The ascending arm of the siphon trap is continued up to such a height as it may be thought desirable that the water should stand in the basin. The

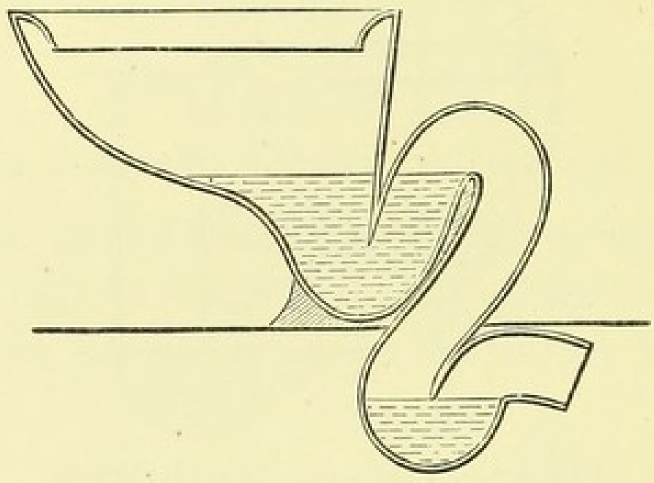

FIG. 18.—Dececo Water-Closet.

descending arm of the siphon ends in a discharging trough, similar to that of Mr. Rogers Field's flush-tank. When the closet is flushed, siphon action is started, and the water and excreta are rapidly discharged. The waste-preventing cistern used with this closet is provided with a branch pipe conveying water from the "supply-pipe to the cistern" to the "supply-pipe to the closet;" so that when the cistern is refilling, the W. C. basin is also being recharged with water, constituting a species of "after-flush."

Water-waste preventing cisterns should be used with each of these three forms of closet, both for economy of water and to break the connection between the house cistern, used for drinking water, and the W. C. basin. Where there is no house cistern, the water being supplied by constant service, the water-waste preventer is especially necessary. Numerous epidemics of enteric fever have been traced to the ascent of foul air or liquid filth from W. C. basins up the supply-pipes into the water mains, with which they were directly connected. One of the simplest forms of water-waste preventer merely has a spindle valve in the cistern on the supply-pipe to the

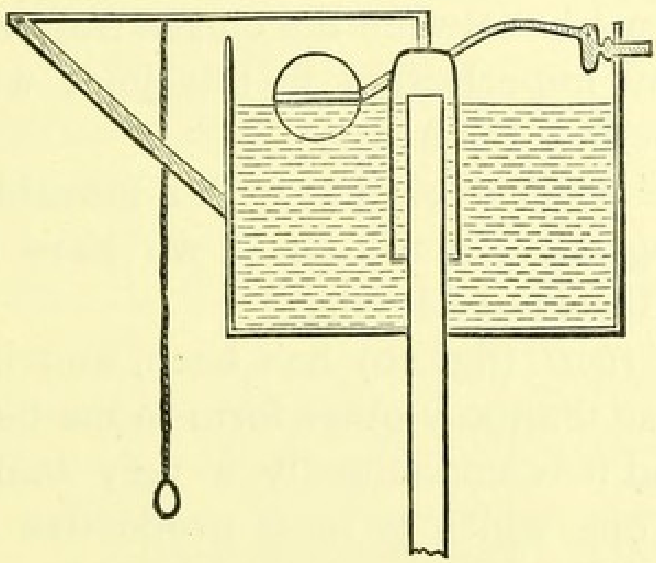

FIG. 19.—Siphon Action Water-Waste Preventer.

closet, which can be raised by pulling a chain attached to a lever, when the water—2 or 2½ gallons—is discharged. When the lever is depressed by the chain, the ball-valve is raised, and no more water can enter the waste-preventer as long as the chain is held. The chain must be held until the waste-preventer is empty.

The best form (fig. 19) of water-waste preventer is that with a siphon action. A very short pull of the chain will put the siphon in action, when the whole contents of the cistern are discharged. No more water can then escape until the cistern is refilled and the chain released and again pulled. Its especial advantage is that it is emptied by a very short pull of the chain—an important factor in the proper flushing of closets used by careless persons.

The closets already described are more especially useful out of doors and in the basements of houses, where they can be directly connected with the drain. The joint between the china or stoneware trap and lead soil-pipe is difficult to make perfectly secure. Therefore it is better for these closets, where they must be connected to a soil-pipe, to have lead traps, a wiped joint being made between the closet trap and the soil-pipe, as any imperfection in this joint will allow foul air to escape into the house.

Under the head of closets with a movable apparatus for retaining water in the basin, we have the Pan, the Valve, and the Plug Closets.

The *Pan closet* (fig. 20) has been, and is still, more largely in use than any other form in the better class of houses; and it is undoubtedly a very badly contrived closet, and one which is most productive of nuisance. When water-closets were first introduced into this country, between 50 and 60 years ago, the Bramah or valve-closet was the one generally used. The Bramah closet was, however, superseded by the pan closet, on account of the smaller cost of the latter, and the fact that no overflow pipe to the basin was necessary—water flowing over the sides of the pan—as it was for the Bramah with its watertight valve.

The pan closet consists of a china basin, shaped like an inverted cone, with its outlet guarded by a movable metal pan, which retains water in the basin; and for this purpose the pan must be of considerable size. On

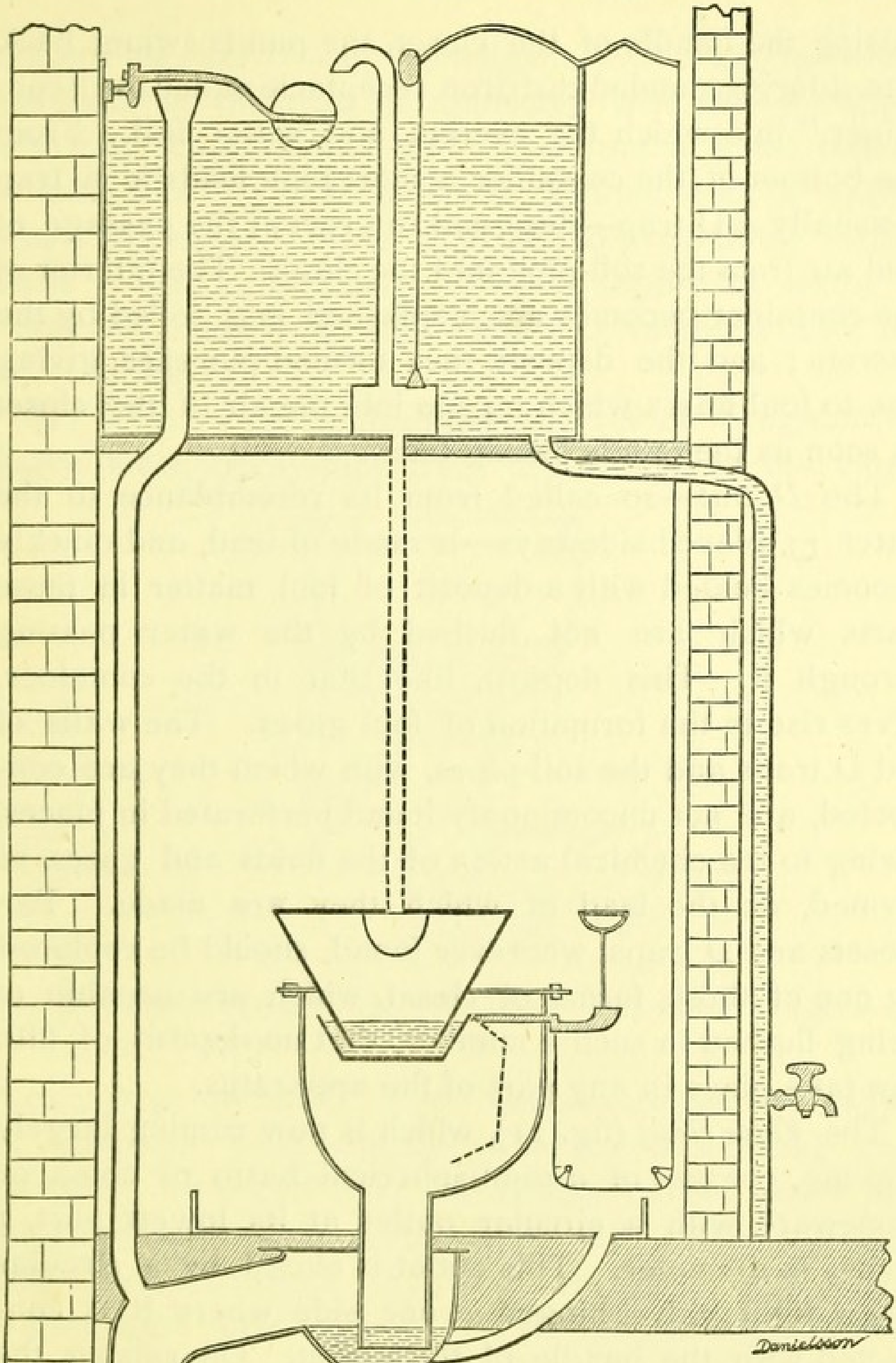

FIG. 20.—Pan Closet with D trap, supplied from drinking water cistern. Standing waste-pipe directly connected with unventilated soil-pipe. Waste-pipe of safe-tray enters the D trap.

raising the handle of the closet, the pan is swung back into a large rounded cast-iron receptacle called the "container," into which the excreta and water fall. From the bottom of the container a short pipe leads to a trap —usually a D trap—designed to prevent the passage of foul air from the soil-pipe into the closet. The interior of the container becomes much splashed and soiled by the excreta; and the deposit thus formed putrefies, giving rise to foul gases which escape into the air of the closet as soon as the pan is swung back.

The *D trap*—so called from its resemblance to the letter ᗜ, placed sideways—is made of lead, and quickly becomes coated with a deposit of foul matter in those parts which are not flushed by the water passing through it. This deposit, like that in the container, gives rise to the formation of foul gases. The walls of old D traps and the soil-pipes, with which they are connected, are not uncommonly found perforated in places, owing to the chemical action of the fluids and gases, so formed, on the lead of which they are made. Pan closets and D traps, wherever found, should be replaced by one of those forms of closet, which are capable of being flushed in such a manner, that no deposit of filth can take place in any part of the apparatus.

The *Valve closet* (fig. 21), which is now coming largely into use, consists of a semi-spherical basin of china or stoneware, with a circular outlet at its lowest part, 3 inches in diameter. This outlet is closed by a circular water-tight valve, hinged at one side where it is connected with the handle of the closet. On raising the handle, the free edge of the valve is depressed into a metal valve-box, just large enough to allow the valve to assume a perpendicular position. The valve-box is connected at its lower part with a trap—preferably a siphon trap or an Anti-D trap formed of 4-inch lead pipe—and the outlet of this trap is connected with the soil-pipe. The valve closet should be flushed from a small cistern holding 6 or 8 gallons of water, and not from a water-waste preventer, as it is necessary to provide an "after-flush"; that is to say to allow a supply of water to enter the basin after the handle is released and the valve closed.

To secure an after-flush, some form of "regulator" valve in the supply-pipe from the cistern to the closet

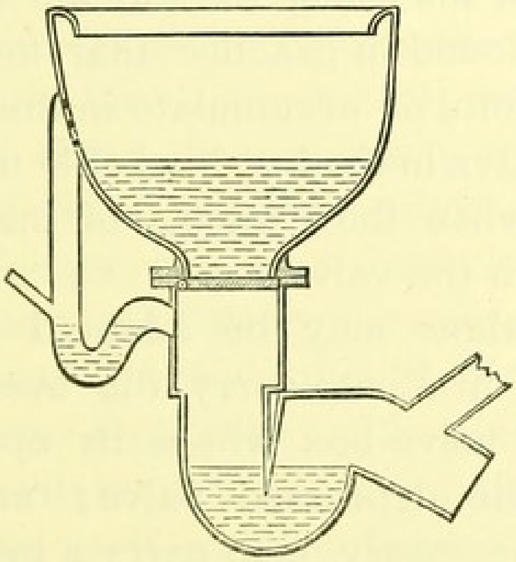

FIG. 21.—Valve Water-Closet with Anti-D Trap and Anti-Siphonage Pipe.

basin, must be used. The "bellows regulator," which is commonly used, consists of a piston working in a cylinder, connected with the handle of the closet and with the valve in the supply-pipe. The cylinder is provided with an escape pipe for air, on which is a tap to regulate the speed with which the piston falls. When the handle is raised, the valve in the supply-pipe is opened and the piston also is raised; but on letting go the handle—the valve to the closet basin being then closed—the valve on the supply-pipe is kept open, admitting water to the basin, until the piston has completely fallen. The amount of after-flush, which is directly proportional to the slowness with which the piston sinks in the cylinder, can be regulated to a great nicety by the tap on the air escape pipe.

As the outlet to the closet basin is guarded by a water-tight valve, the basin is liable to overflow from too much after-flush, or from the throwing in of slops. It is necessary therefore to provide an overflow pipe to the basin; this is usually carried from near the top of the basin into the valve-box below, after forming an S bend, to prevent the ascent of foul air from the valve-box. But it is found in practice that foul matters may find their way into, or accumulate in the overflow pipe, and that the water in the bend is liable to be drawn out by siphonage, when the contents of the basin are discharged through the valve-box.

Two precautions may be adopted to obviate this difficulty. The first is to carry the overflow pipe into that side of the valve-box where its open end will be protected by the depressed valve; and the second, which is most necessary, is to carry a branch pipe from the supply-pipe, near the regulator valve, into the bend, whereby the water is renewed at each use of the closet. The basin of the closet should be provided with a flushing rim.

There is very little risk of the deposition of filth in any part of the apparatus, as the large volume of water, which the basin can contain, effectually flushes the small valve-box and trap beneath. Occasionally the valve-box is enamelled inside to prevent corrosion. The chief disadvantage of the closet is that, unless carefully used, the valve becomes in time leaky, allowing the water in the basin to escape, and possibly foul air to ascend into the general air of the closet.

The *Anti-D trap* (see fig. 21) is an S bent pipe like the siphon trap, but the calibre of the pipe is diminished in the bent portion which holds the trapping water, and the bend of the pipe beyond the trap instead of being circular is squared. These properties cause some resistance to the passage of water through the trap, and tend to prevent both *siphonage by suction, i.e.*, the drawing of the water in the trap by the passage of water down the soil-pipe from a higher level, and *siphonage by momentum*, which may occur in plain siphon traps by the water discharged from the water-closet sweeping through the trap, none remaining behind to form the water-seal.

In the *Plug closet*, the basin and trap are usually cast in one piece of china or stoneware, the basin above being separated from the trap (siphon) below, by a solid plug or plunger, by which water is retained in the basin. The cistern and flushing arrangements may be the same as those for the valve closet, an after-flush being necessary for both alike. The plug, which is connected directly with the handle, is usually perforated by a channel bent on itself so as to form a trap, and thus provides an overflow to the basin, permitting water to pass through the plug to the trap beneath. Sometimes these closets are used without the trap beneath; but in both plug and valve closets a siphon trap is necessary to prevent the passage of foul air from the soil-pipe when the closet is discharging its contents. The plug or plunger is liable to become soiled, and being out of sight escapes cleaning; this constitutes a disadvantage in use. The trapless closet, in which the basin can be jointed to a lead trap beneath, is preferable, for reasons before stated, to the closet with basin and trap in one piece, where connection must be made to a lead soil-pipe.

For valve and plug closets as for those of the first class, to ensure efficient flushing, the cistern must be at least 4 feet above the seat, and the supply-pipe not less than 1¼ inch in diameter. The valve and plug closets are under the disadvantage of having a space between the water in the basin and the water in the trap, from which air—possibly foul—escapes into the general air of the closet when the contents of the basin are being discharged. But they have this advantage over those of the first class, that the larger quantity of water in the basin renders them more cleanly in use. The Dececo closet has been so recently invented that we are unable to speak as to its practical working. Possibly it may possess the advantages, without the drawbacks, of both the classes of water-closet we have described.

On the floor beneath the closet basin is usually placed a lead or zinc *safe-tray*, to catch any overflow. This tray should be provided with a waste pipe, which must be carried through the wall into the outer air, its end being covered by a brass flapper to prevent cold currents of air passing into the house. It was formerly the custom to connect this waste pipe with the D trap (see fig. 20), under the closet basin, thereby permitting foul air to enter the house at all times.

Water-closets should be placed against an outside wall of a building, in which is a window reaching to the ceiling. Where possible they should be separated from the house by a well ventilated lobby; for it is important that air from the closet should find an easy exit to the outer air, and not pass into the house, as so often happens when water-closets are placed in dark unventilated corners.

The *Trough closet* (fig. 22) is specially useful in large establishments, as Hospitals, Schools, Workhouses, and

Asylums, and in the courts and alleys of towns. One apparatus serves for the use of several people at the same time, and the flushing can be rendered automatic. The closet consists of an open trough, usually of stoneware, with rounded bottom, of varying length according to the number of compartments desired. The trough should have a slight incline towards the drain; and by means of a weir at its lowest end should be able to retain sufficient water to cover the bottom for its whole length. It should terminate in a siphon trap pro-

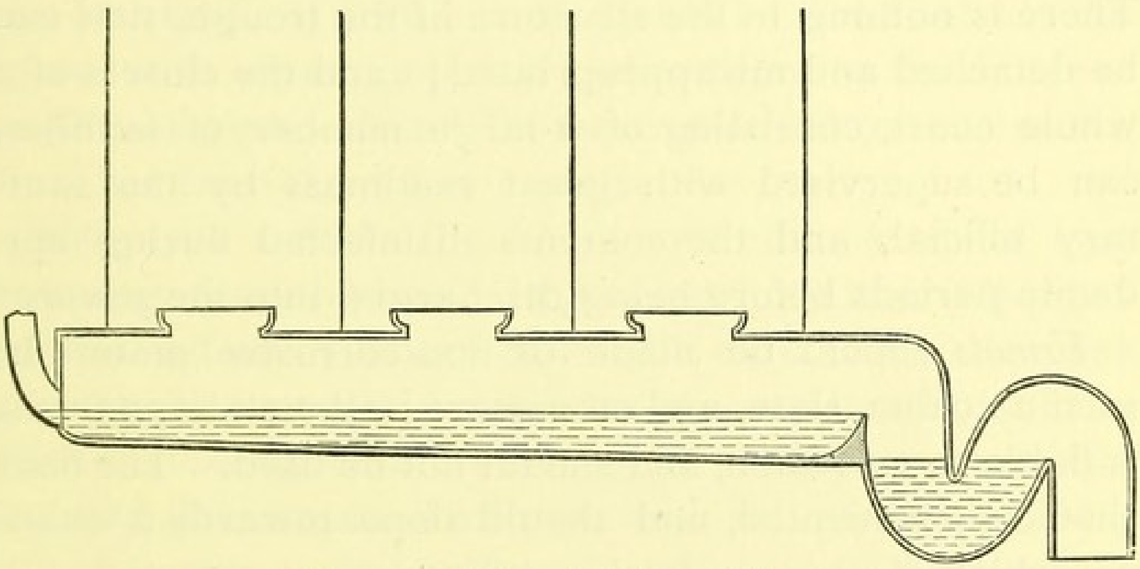

FIG. 22.—Trough Water-Closet.

tected by a grid, to keep back articles improperly thrown in, before joining the drain. Each seat over the trough should be in a separate wooden compartment. The closet may be flushed by means of a Field's Annular Siphon Flush Tank (see fig. 14) of capacity proportional to the length of the trough to be flushed.

The frequency of discharge of the tank and flushing of the trough, can be regulated by adjusting the tap through which the water enters: the merest dribble is usually quite sufficient. This tank in practice works admirably, "dribbling" and "continuous" action being impossible, if it is placed on a perfectly level surface with the discharge pipe quite plumb.

Trough closets might with advantage be more extensively used than they are in the poor districts of large towns, to replace the wretched "long hopper" basins, which are nearly always in a filthy condition and wretchedly flushed. The trough closet is admirably adapted to the wants of a poor population; the flushing is automatic, and if the tank is placed in a separate locked compartment accessible only to the nuisance inspector, it is out of reach of mischievous interference. There is nothing in the structure of the trough, that can be detached and misappropriated; and the closets of a whole court, consisting of a large number of families, can be supervised with great readiness by the sanitary official, and the contents disinfected during epidemic periods before being discharged into the sewer.

Urinals should be made of non-corrosive materials, such as china, slate, and stoneware; all metal apparatus is liable to corrosion, and should not be used. The floor should be cemented, and should slope towards a channel which discharges into a siphon trap connected with drain or soil-pipe. Urinal basins may be made of china or stoneware, and constructed so as to retain water. Their waste pipes should discharge over the channel in the floor. The best kind of flush is that from siphon-action flush tanks which discharge automatically at regular intervals. Wright's self-flushing urinal is an ingenious invention which, by means of an arrangement of siphons in connection with the cistern, secures a flush to the urinal basin as soon as urine flows out of the basin down the waste pipe.

Slop-sinks should be used only where it is objectionable to discharge slops through the water-closets. They are usually short hopper china basins with a siphon trap below, protected by a grid to keep back the larger foreign bodies which might obstruct the pipes. They should be provided with a flushing rim, and flushed from a water-waste preventer.

Soil-pipes are used to receive the contents of water-closets, urinals, and slop-sinks only. They should be circular in section, and 3½ or 4 inches in diameter, these being the most convenient sizes for ordinary use. They should be of drawn lead, 7 lb. to the square foot, or 9 lb. to the square foot for very high buildings, without any longitudinal seam; and should be fixed outside the house, with wiped (soldered) joints between the different lengths of pipe. Lead T pieces are used to receive the branches from the water-closets.

Soil-pipes outside the house are often made of cast iron or galvanized iron. In America cast iron soil-pipes are insisted on by Board of Health regulations, especial precautions being laid down for the construction of the joints between the different lengths. To prevent oxidation and the formation of rust, iron soil-pipes should be coated inside and outside with the magnetic oxide of iron (Barff's process), with hot coal-tar pitch, or with Angus Smith's solution. The joints between the different lengths must be caulked with oakum and lead, or with Spence's metal, and the joints between the iron pipe and the lead T pieces from the closets "should be made with a brass ferrule, caulked in with lead, the lead pipe being attached to the ferrule by a wiped joint."*

With these precautions, and under skilled workmanship, iron soil-pipes may be used outside a house. Stoneware, zinc, or wrought iron should never be used for soil-pipes. The proper fixing of the soil-pipe, to

* House-drainage, by W. Eassie, *Our Homes*, p. 635.

ensure its being perfectly rigid, is a point of importance: if not securely fixed there will be a strain on some or all of the joints with the result of their becoming insecure. Outside soil-pipes should be connected below with the house drain by a plain bend; and all soil-pipes, whether inside or outside the house, should be carried up full bore above the entrance of the branch from the highest water-closet to the top of the house (fig. 23) above the ridge of the roof, clear of all windows and chimneys, their ends being left open or covered merely with wire gauze. Where the soil-pipe must be inside the house, it should not be connected directly with the house drain, but should discharge into a siphon disconnecting-trap (soil-pipe intercepter, fig. 24) with an air inlet outside the house—to admit of a current of fresh air passing up the soil-pipe—the drain in these cases being ventilated separately by means of a 4-inch pipe carried up above the roof.

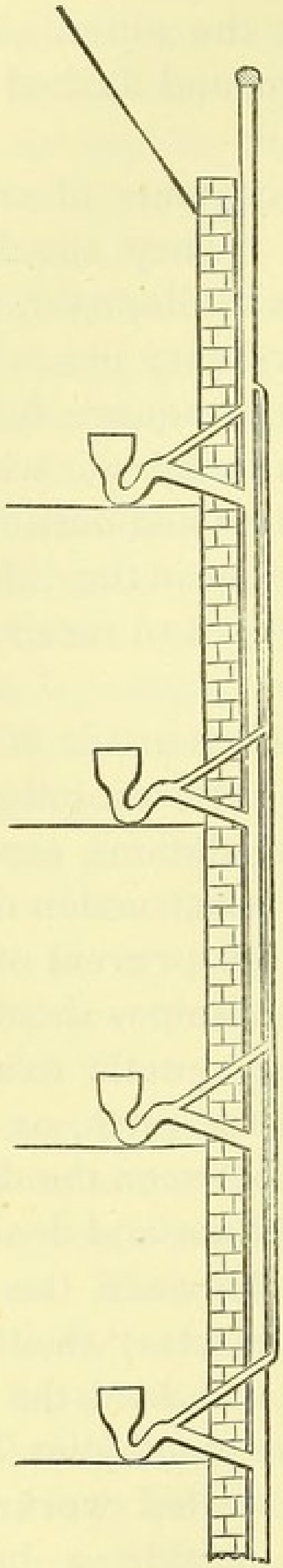

FIG. 23.—Soil-Pipe and Ventilator, with Anti-Siphonage pipes from the W.C. branches.

Where one soil-pipe receives the discharges of several water-closets on different floors, the passage of the contents of one of the upper closets down the soil-pipe may cause the water in the trap of one of the lower closets to be drawn off, owing to the suctional force of the downward current of air caused by the descent of the liquid in the soil-pipe. To prevent this siphonage taking place, a 1½ or 2-inch ventilating pipe should be carried up from every branch pipe but the highest,

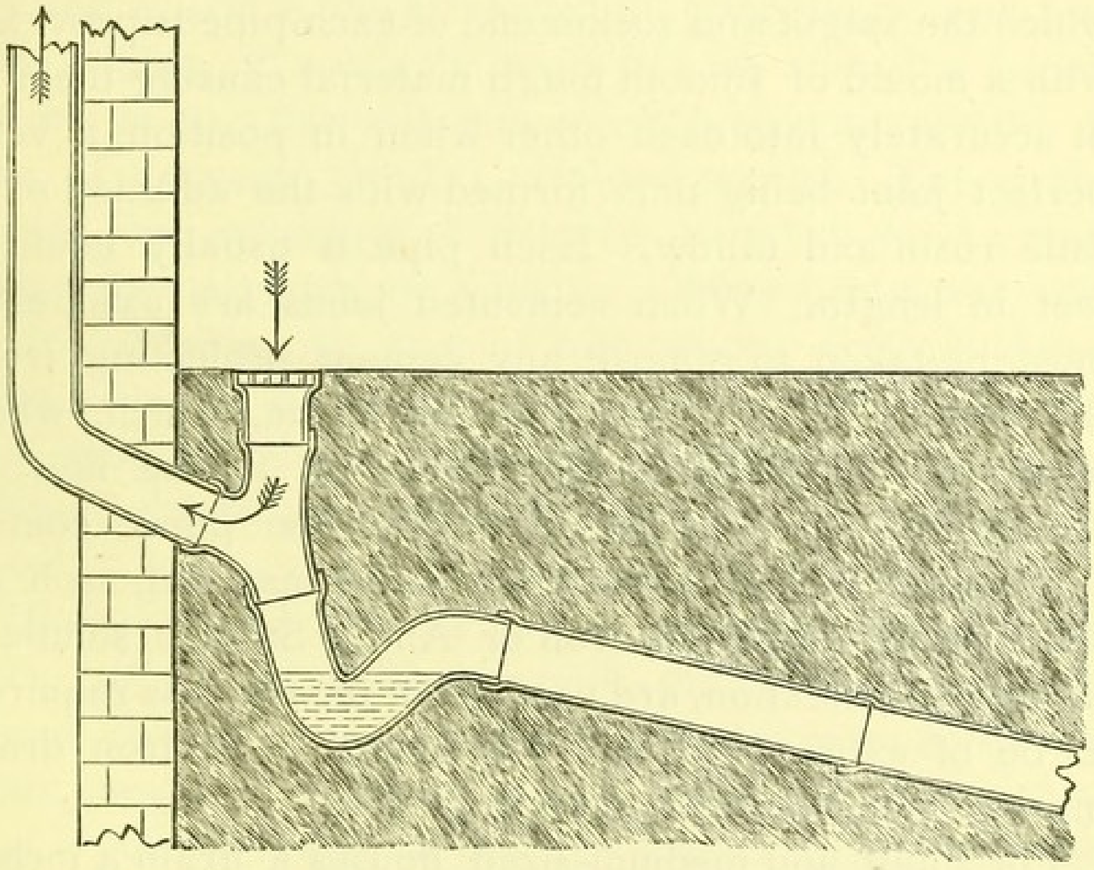

FIG. 24.—Soil-Pipe Intercepter for inside Soil-Pipe.

close to but beyond the trap (on its soil-pipe side), and joining with one another on their way up outside the house, they may be connected with the ventilator to the soil-pipe (fig. 23). By this means the water-closet traps will not be disturbed by the passage of liquid down the soil-pipe, for air will be sucked down these ventilating pipes to restore the disturbed equilibrium.

Rain water pipes from the roof must on no account be used as soil-pipes and ventilators, for during heavy rain, when it may be most necessary to give a safe exit for displaced drain air, they will be useless as ventilators, and foul air may be forced through water-closet traps into the houses.

House drains are usually constructed of circular, glazed, stoneware socketed pipes with cemented joints, or with Stanford's Patent joints or Doulton's modification, in which the spigot and socket end of each pipe is provided with a mould of smooth tough material causing them to fit accurately into each other when in position, a very perfect joint being thus formed with the addition of a little rosin and tallow. Each pipe is usually made 2 feet in length. When cemented joints are used, care must be taken to remove any cement projecting from the interior of the joint into the drain, which, when hardened, might form an obstruction to the flow of sewage through the drain. Cast-iron pipes coated inside and out with some preservative material, such as the magnetic oxide of iron or Angus Smith's solution, to prevent oxidation, are used when the drain is required to be of extra strength. The joints of an iron drain must be caulked with lead and gasket.

For small and medium-sized houses a drain 4 inches in diameter is the proper size; for large houses a 6-inch drain may be used, and for institutions or establishments consisting of several buildings, a 9-inch drain may be required. The smaller the drain the better the flushing and removal of deposit, but the drain must in all cases be large enough to carry off at all times all the rainfall over the area drained, as well as the maximum flow of sewage proper of the house. A volume of water sufficient to make a 4-inch pipe run full, causes a 6-inch pipe to run less than half full, and a 9-inch pipe only about a quarter full, when all three are laid at the same inclination.

The pipes must be laid (with the socket end pointing upwards towards the head of the drain) on a perfectly smooth incline of hard ground, or where passing under the basement of a house on a bed of cement concrete, and in this case it is often the practice to cover and embed them as well with cement concrete. The gradient for a 4-inch drain should, if possible, be not less than 1 in 40, of a 6-inch drain 1 in 60, and of a 9-inch drain 1 in 90; this will give in each case a velocity of flow of between 3 and 4 feet per second. The drain should not, wherever it can be avoided, be carried under the basement of a house. Where, however, this is unavoidable, the special precautions noticed above must be taken, and at the point where the drain leaves the premises, the wall should be supported by a relieving arch to prevent settlement and fracture of the pipes.

Drains should be laid as far as possible in straight lines. If a bend is necessary, it should be effected by means of a pipe curved to the proper degree. A branch drain should be made to join the main drain by means of a V junction pipe, so that the branch current may be flowing nearly in the direction of the main current, thus causing no obstruction at the point of union. In large houses it is very often impossible to carry the drain in a straight line for its whole length. It is advisable in these cases, at every change of direction, to provide means of inspection by manhole chambers, the drain being continued through the floor of the chamber by a suitably curved channel pipe, *i.e.*, a pipe divided longitudinally in half. Into these inspection chambers (fig. 25) the branch drains also may be made to discharge by means of short curved channel pipes emptying over the main channel. Winser's curved channel pipes should be used when connected with a high soil-pipe. By this system of manhole chambers, the drain—which runs in a straight line from manhole to manhole—can be inspected and cleared of deposit or obstructions without breaking into it. Where it is necessary to connect a small pipe with a larger pipe, the junction should always be effected by means of a taper or diminishing pipe.

The *disconnection of the house drain* from the public

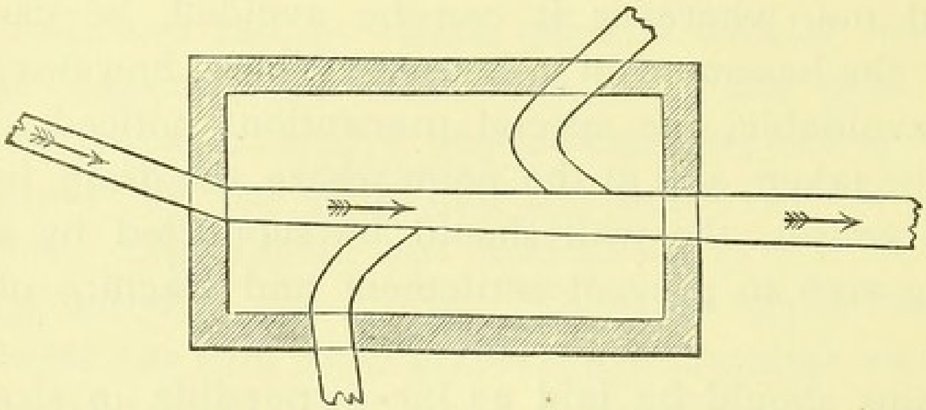

FIG. 25.—Plan of Inspection Chamber for House Drain, where it changes its direction.

sewer is a matter of the greatest importance, experience having proved the absolute necessity of preventing the entry of air from the common sewer into any part of a house or its drainage arrangements. Disconnection is effected by interposing a siphon trap between the house drain and the sewer, and advantage is taken of this break to provide a means of inlet for fresh air into the house drain at this point. The point usually chosen for disconnection is where the house drain leaves the premises, and before its junction with the sewer. If the house drain is provided with a ventilating pipe at the further end, air, admitted on the house side of the disconnection trap, will produce a current from the lower opening to the higher, and constant circulation will thus be established in the drain and soil-pipe, preventing any accumulation of foul air.

The simplest form of disconnecting apparatus consists of a siphon trap with fresh air inlet, formed of stoneware pipes. There are several varieties of this sort of trap sold, under the names of "sewer-air-interceptor," "sewer-air-trap," etc. The points to be observed in choosing a trap of this description, are:—(1) where the drain is a 6-inch or 9-inch pipe, the siphon should be a size smaller than the drain; (2) there should be a fall of an inch or more from the level of the discharging end of the house drain to the surface of the trapping water; (3) the siphon should provide an adequate seal of 2 or 3 inches of water; (4) the inlet to the siphon should be nearly vertical, whilst the outlet rises at an angle of not more than 45°. These qualities, except (3), are necessary to ensure efficient flushing of the trap; and to further attain this end, the drain should be laid with a slightly greater fall before its junction with the trap. The inlet to the siphon is continued up by a vertical pipe to the surface of the ground, and there covered by an open iron grating, to provide the necessary inlet for fresh air.

In larger houses it is now usual to provide a *disconnection manhole chamber* (fig. 26), instead of the simple trap above described. This chamber is built of glazed brickwork in cement upon a bed of concrete. The drain is continued through the floor of the manhole in the form of a glazed channel pipe, from which the floor—made of cement—slopes up at an angle of 30° to the brick walls of the manhole. The branch drains, in the

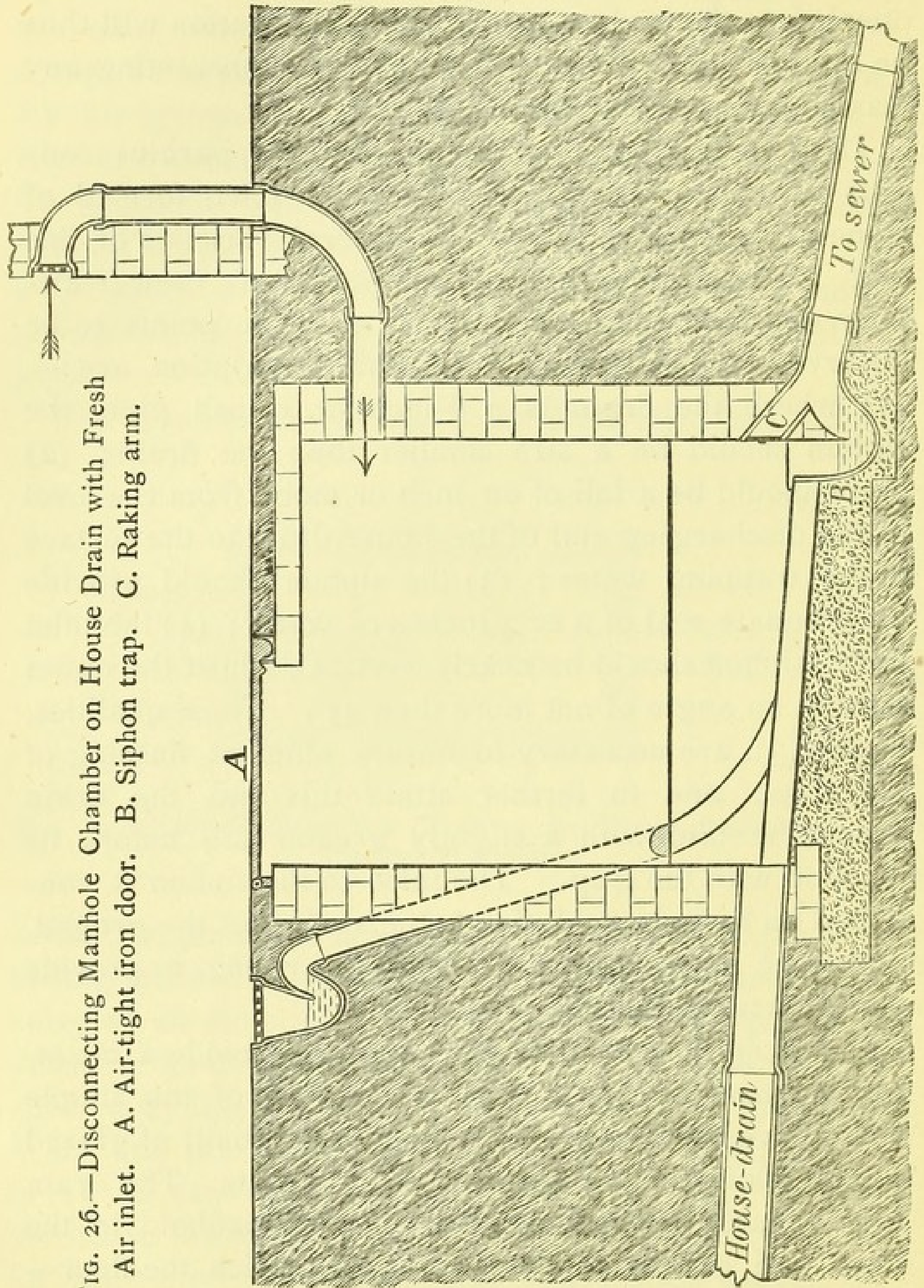

FIG. 26.—Disconnecting Manhole Chamber on House Drain with Fresh Air inlet. A. Air-tight iron door. B. Siphon trap. C. Raking arm.

form of suitably curved channel pipes, are made to discharge over the main channel, which itself discharges into a siphon trap. The siphon trap should be provided with a "raking" arm, one end of which opens into the manhole, the other end being connected with the drain beyond the trap. This arm is to permit of obstruction being removed from the drain between the siphon trap and the sewer; when not in use, the manhole end should be closed with a tile set in cement. The manhole chamber may be closed above by an air-tight iron cover; and the fresh air should then be admitted into the chamber by a 6-inch pipe, the manhole end of the pipe being opposite the entrance of the drain, whilst the end open to the air is covered by an iron grating. Where the disconnection chamber is some distance from the house, fresh air may be admitted by perforations in the iron cover. The chief advantage of the manhole chamber is the readiness with which the drain can be inspected and cleansed.

Where the house drain discharges into a sewer liable to flooding, it is necessary to provide a tide valve between the sewer and drain. The best form of this apparatus is a floating ball valve in an enlargement of the drain, which rises, on the sewage being backed up from the sewer, and closes the outlet to the drain.

For house drains with insufficient gradient, in which deposit is liable to occur, it is advisable to place an automatic flush tank at the head of the drain; by this means the dangers arising from insufficient fall may be to a great extent obviated.

When a house drain has been laid, and before it is covered in, it should be tested for leaks. A simple method is to plug the lower end of the drain and fill it with water. If after standing some time the level of the water at the upper end is found to descend, the drain is not water-tight and the joints should be examined for leaks. Another method, which tests the soil-pipe as well as the drains, is to burn brown paper or some sulphur in a shovel in the disconnection trap or chamber, the air-inlet being closed as soon as the paper or sulphur is well alight; or the drain may be filled with smoke by a forcing apparatus actuated by an air-pump, or by firing smoke rockets into it. Leakages in the drain or soil-pipe will then become evident to both sight and smell. A third method, which is especially applicable for testing drains and soil-pipes which have been long in position, and in which there is no disconnection apparatus, is to pour down the ventilator to the soil-pipe, if there is one, or in default, the highest water-closet, about half an ounce of oil of peppermint, following it up with several gallons of hot water. By this means the smallest leak will be discovered by the sense of smell, as the peppermint is excessively volatile. Soil-pipes and their branches may be tested before the W. C's. are connected, by soldering over the apertures where the traps of the W. C's. are connected with the soil-pipes, and then filling the pipes with water. This is a severe test owing to the great head of water, but $3\frac{1}{2}$-inch lead pipes (9 lb. to the square foot) are found to stand the test well if the joints are well made.

All *waste pipes* from baths, lavatories, sinks, and safe-trays under water-closets, must be disconnected from the drain or soil-pipe by being made to discharge into the open air. The waste pipes from baths, lavatories, and sinks should be of large diameter ($1\frac{1}{2}$ or 2 inches) to ensure rapid emptying of the baths, sinks, etc., and as short as possible; for they tend to become coated internally with a deposit of dirt and soap, which decomposes, and may be productive of nuisance. To prevent foul air from these pipes entering the house, a cast-lead siphon trap should be fixed under every bath, lavatory, and sink (fig. 27); and in the case of kitchen sinks this siphon trap should be provided at its lowest point with a screw cap, capable of removal, in order to clear the trap of sediment and grease. The waste pipes from the upper floors can be carried through the external walls to discharge into the open head of a rainwater pipe (fig. 27), divided if necessary into lengths for this purpose; and every rain water pipe must be disconnected from the drain at its foot, by opening on the iron grating over a stoneware siphon yard gulley. The basement waste pipes may discharge into yard gullies by side inlets (fig. 27). When it is impossible to avoid having a long waste pipe, this must be ventilated by a pipe of its own diameter carried up outside the house to a convenient point.

The *overflow pipes of cisterns* should be made to serve as "warning" pipes, by being carried through the external wall and left open at a point where any escape of water through them would be capable of observation.

The *surface water* from yards and areas should be carried off by those siphon gullies which receive the waste waters from the house (fig. 27), because these gullies are always efficiently trapped in dry weather. Yard gullies used for surface water only, become untrapped in dry weather, owing to evaporation of the water in them. These siphon gullies are connected with branch drains which join the main drain in the inspection or manhole chambers before referred to; they require to be cleansed periodically of sand and dirt which collect at the bottom of the trap.

In large houses it is found that the sand and fat or grease discharged through the kitchen or scullery sink

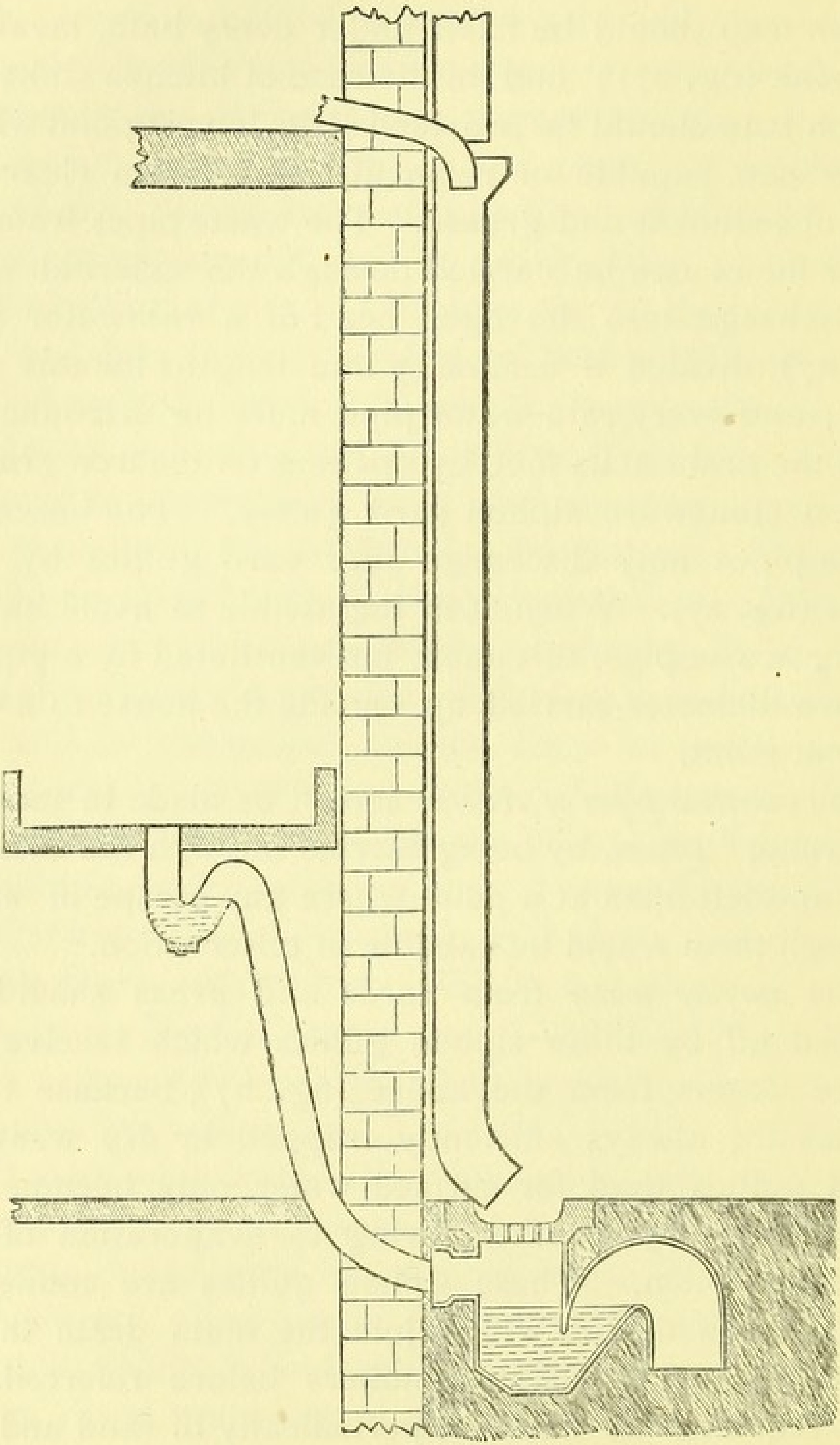

FIG. 27.—Disconnection of Rain Water and Waste Pipe over Siphon Yard Gulley.

are apt to lodge in the drain and form an obstruction. It is usual in such cases to cause the waste pipe (2-inch pipe, trapped under the sink) to discharge into a *grease trap* instead of into a yard gulley. This grease trap may with advantage be also a siphon flush tank (stoneware). The hot water from the sink is cooled on entering a large volume of cold water in the tank, the grease solidifies and rises to the top, whilst the sand sinks to the bottom of the tank. The grease and sand can be removed periodically through an air-tight iron cover at the top of the tank, and the tank should be ventilated by a 3-inch pipe carried up to a point outside the house away from windows.

To carry off the water used for washing down laundries, sculleries, and dairies, the floor should slope to a channel leading to a yard gulley outside the house; in some cases it is necessary to provide a drain, which should be protected by an Antill or some form of lip-trap at the end inside the building, whilst the other end discharges into a yard gulley by a side inlet.

The house drainage arrangements, described above, have for their object:—(1) the speediest possible removal from the house to the public sewer of excretal and other refuse by means of water; (2) the prevention of deposit of foul matter in any part of the drainage system, and of percolation into the soil of polluting liquids; (3) the establishment of a current of air through every part of the soil drains and pipes, in order to disperse any foul gases that may form, and allow them to escape with safety into the open air; (4) the prevention of any entry of air from soil-pipes, drains, and waste pipes, into the house; (5) the exclusion of the air of the common sewer from the house drain and the house; the last being, perhaps, the most important, as the air of the public sewer may at any time contain the active germs of specific disease.

Objects (4) and (5) are to a great extent attained, as we have seen, by means of traps or water-seals, and the question arises "How far do such traps carry out the objects for which they are designed?" Siphon traps are the most cleanly of all traps, because they present no corners or angles where deposit can accumulate, and are most easily flushed clean. Their liability to siphonage we have considered, and we have endeavoured to show that it can be obviated by a sufficient depth of siphon providing an efficient seal of water, and by adequate ventilation. There is, however, another disadvantage common to all water-traps, which is that the water will absorb gases on one side of the trap, and give them off on the other, so that foul air from the drain or sewer may be given off—only, however, to an inconsiderable extent—into a house, notwithstanding the presence of the trap. The only remedy for such a state of things is the prevention of foul air accumulations by adequate ventilation. We have seen that this is possible in properly designed house drainage, and it only remains for the public authorities in charge of the public sewers to take the necessary precautions to prevent the formation of foul gases in the sewers, or to disperse them when formed. The proper ventilation of drains and soil-pipes can only be effected where there is an inlet for fresh air at one end of the system, and an outlet for foul air at the other end. Where there is an outlet but no inlet, the pipes must be always full of foul air, though not under pressure; for there can be then no renewal of the air in them by the passage of fresh air currents.

Defective Sanitary Arrangements in Houses.

We have already indicated the principles on which houses should be drained, and the chief methods by which these principles may be carried into practice. In examining houses, all sorts of appliances and arrangements will be found, departing more or less from the sound principles we have laid down, and we will now briefly describe a few of the sanitary defects more commonly found in houses.*

Drains, rectangular or oval in shape, constructed of bricks set in mortar without any cement, and of large size (18 inches or more in diameter), are not unusually found running under the basements of houses. These brick drains, although originally intended only to carry off surface and house waters, will be found to receive the water-closet discharges as well. They invariably leak, for the mortar becomes loosened from the bricks, and water finds its way out through these open spaces; in some cases all the liquid runs out of the drain to saturate the surrounding soil, whilst the solids accumulate in the drain until it is completely blocked. As the brick drain communicates directly with the sewer, rats find their way into it, and pushing through the loosened bricks, form runs under the house—sometimes into the larder—which become passages for foul air. To ascertain if a brick drain exists under a house, the ground must be taken up, or the sewer can be entered, if large enough, and the drain examined where it joins the sewer.

Pipe drains are always preferable to leaky brick

* For further information on this subject reference may be made to Professor Corfield's Article in *Our Homes*.

drains, but all sorts of mistakes are made in laying pipe drains, and the resulting evils are similar to those arising from brick drains. In the first place the pipes may be of improper material, such as unglazed porous earthenware. If glazed stoneware socketed pipes are used, the drain may be laid for the whole or part of its length with insufficient fall, or with a fall the wrong way. Again the pipes used may be--and generally are —much too large; 9-inch pipes where 4-inch would be sufficient, or the pipes may be laid the wrong way (fig. 28)—with the socket end downwards or towards the sewer.

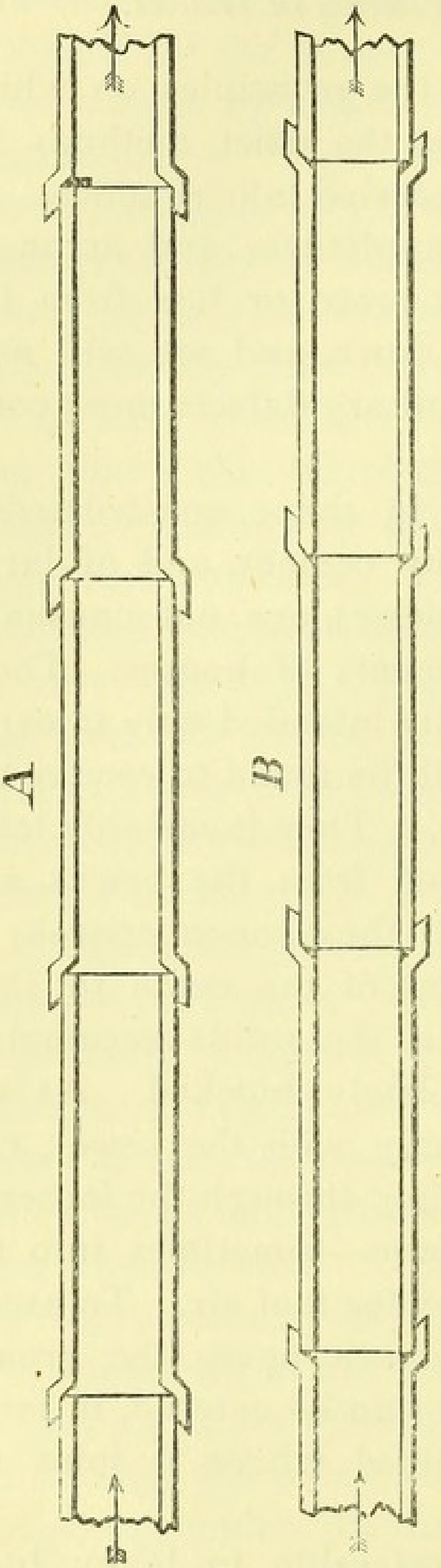

Fig. 28.—A. Drain laid the right way. B. Drain wrongly laid.

The pipes are sometimes laid dry, *i.e.*, without any luting material in the joints, or the luting material used may be clay, which is soon washed out of the joints. Even where the joints are luted with cement, if the drain is laid on uneven ground, settlement takes place and the cement joints become cracked and leaky.

Bends in drains are often made by fitting straight pipes into one another, the result being an open joint on the side of the drain with the greater curvature. The junctions of branch drains are frequently made by knocking a hole in one side of the main drain sufficiently large to receive the end of the branch, which projects more or less and constitutes an obstruction, the hole being filled in with clay or cement, Even where proper junction pipes are used, the junction may be made the reverse way, so that sewage from the branch enters the main drain in a direction opposed to the flow of sewage in it.

Where a small pipe joins a larger pipe, the junction is often effected without a diminishing pipe by placing the socket end of the small pipe into the socket of the larger pipe, and the joint that results is most defective (fig. 29). In this case also, the smaller pipes will be all laid the wrong way (with the socket end downwards), and junctions will be wrongly connected in a direction opposed to the flow of sewage. The evils arising from such defects in drains, are leakages of foul liquid into the soil, escape of foul air, and formation of foul deposits in the drains, leading eventually to complete obstruction.

House drains were, and are still, almost invariably connected directly with the common sewer, an iron flap-trap only being placed over the opening of the drain into the sewer. This flap-trap affords no protection against the passage of foul air or rats from the sewer into the drain. It was formerly the custom to place a *dip-stone trap* (fig. 30) on the course of the drain to prevent the passage of foul air up it. It consisted of a brick chamber of some depth retaining water, into which dipped a stone fixed in the roof of the trap. This trap not being self-cleansing becomes choked with

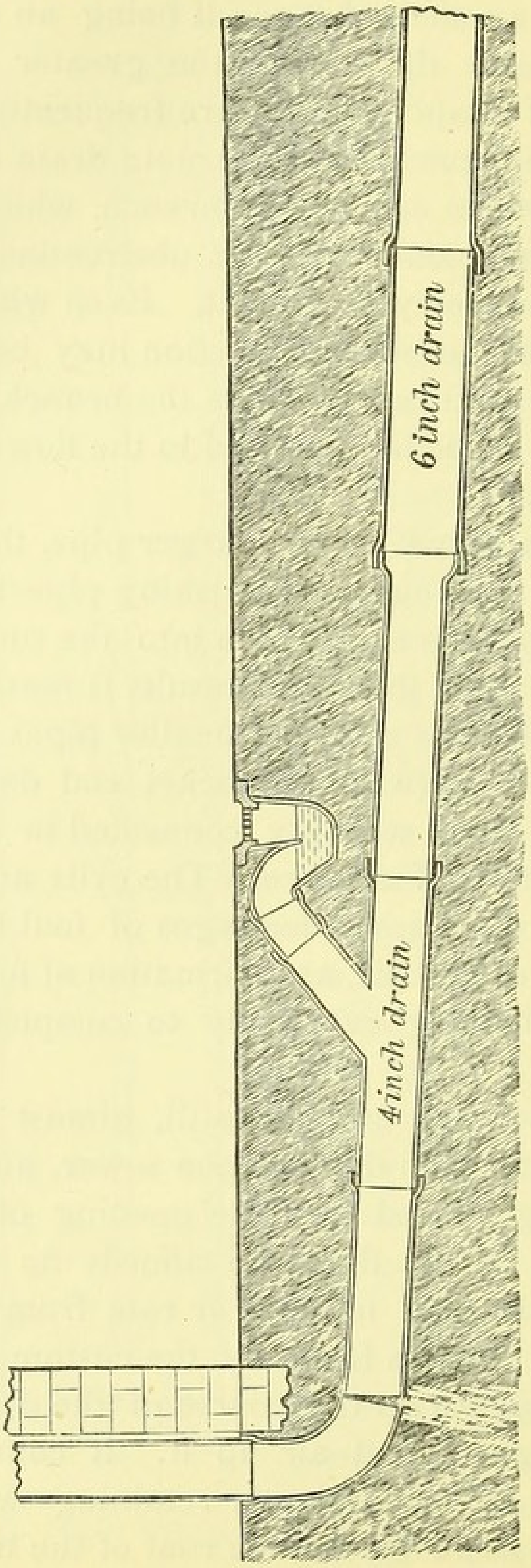

FIG. 29.—4-inch drain laid the wrong way for want of diminishing pipe.

deposit, which putrifies and causes a most offensive nuisance. Where disconnection is practised, it is not uncommon to find siphons too large, or of improper construction, and incapable of complete flushing; in some cases the siphon is so constructed that the outlet is higher than the inlet, with the result that the sewage is backed up in the drain (fig. 31). One of the worst forms is that in which a vertical access pipe rises from

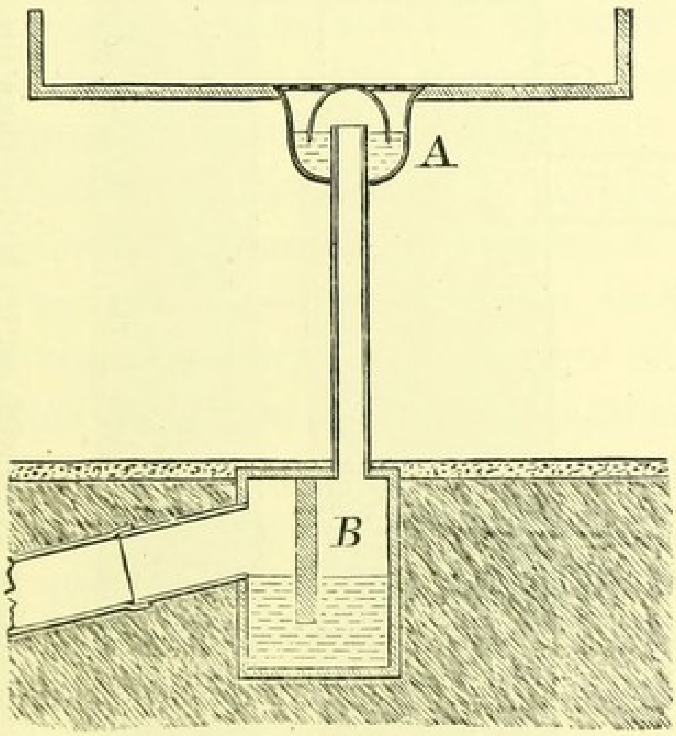

FIG. 30.—Sink with Double Trapped Waste Pipe. A. Bell-Trap. B. Dipstone Trap.

the dip of the trap, for in this pipe solid matters are bound to accumulate.

Soil-pipes are very commonly found fixed inside the house. If of lead, the pipe may be longitudinally seamed for its whole length, perforations being frequent in the seam of solder, and the joints formed by slipping one length of pipe inside the other. Cast-iron pipes with loose packed joints occasionally do duty as soil-pipes, and may perhaps take rain water as well. Zinc is occasionally used for soil-pipes; where it has been

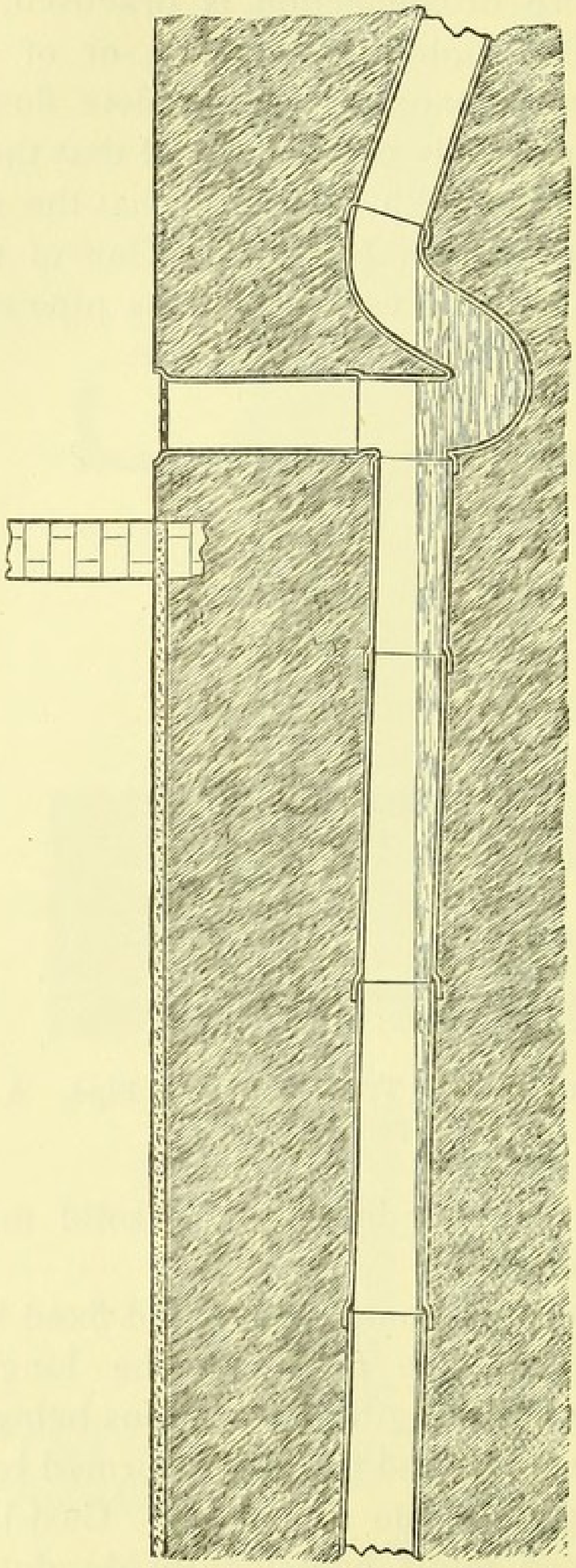

FIG. 31.—Disconnection Trap with outlet higher than the inlet.

long in use, it is sure to have numerous perforations.

In old houses the soil-pipe is almost invariably unventilated, that is to say, it is not open, but closed at its highest point. The foul air in unventilated pipes acts on the lead (or zinc) walls, and gradually dissolves them, forming holes through which foul air or liquids escape. But such closed soil-pipes are often in reality —though not so intended—ventilated into improper places, for the foul air in drain and soil-pipe is sure to find some way out. Where the waste pipes of baths, sinks, or lavatories, are connected directly with the D trap under a water-closet, with the soil-pipe, or with the drain, foul air will find its way out through these waste pipes and through bends in them, or through bell-traps into the house. Another ready means of exit is the waste pipe to the safe-tray under a bath or water-closet, when connected with the soil-pipe or drain.

But the most important, because the most dangerous, is the direct connection of the overflow or standing waste pipe of a cistern used for drinking water, with the drain or soil-pipe (see fig. 20). The foul air rises through this pipe and escapes under the lid of the cistern over the surface of the water, which readily absorbs the foul gases and suspended matters (possibly disease germs), and a most dangerous pollution is thereby caused. Other means by which foul air can escape from unventilated drains, are bell-traps (fig. 30) in the basement of the house (kitchen or scullery) or in yards and areas, and rain water pipes directly connected with the drains. In this last case also, foul air will escape through the loose joints of these pipes, which may be in close proximity to bedroom windows.

With an unventilated drain, water-traps—even the best designed, as we have already seen—are not effectual safeguards against foul air entering the house. Bell-traps, which present so small a seal of water, and which are usually choked with rubbish, are worse than useless to prevent the passage of foul air. It is very usual too to find the bell removed and the trap consequently gone, because the obstruction to the flow of water through them is so great. The aspirating effect of fires inside a house must not be lost sight of; the draught up the chimney tends to draw air towards it from any opening into the room, and thus it often happens that drain or sewer air is drawn into living rooms.

Where some attempt has been made to ventilate the soil-pipe, it is often either most absurdly inadequate, as when a 1-inch pipe is carried up as ventilator to a 4-inch soil-pipe, or it is improperly carried out, as when a rain water pipe acts as ventilator to the soil-pipe. Besides the danger of foul air escaping into windows, especially attic windows under which the rain water pipe often commences, it is obvious that during a storm of rain when it is most necessary to provide a safe means of exit for displaced drain air, the ventilator will be running full of water and will be useless.

The pan closet and D trap are perhaps the most common of all sanitary (or insanitary) appliances. They must, wherever found, be replaced by improved forms of closet and trap. The pan closet is usually supplied with water from the same cistern that supplies drinking water in the following manner (fig. 20) :— the supply-pipe is connected with a small trapping-box at the bottom of the cistern. Water is admitted into the trapping-box by a spindle-valve guarding an opening in the top of the box, this valve being connected with the handle of the water-closet by wires and cranks. An air-escape pipe rises from the trapping-box to give exit to displaced air. When the handle of the closet is pulled up, the spindle-valve is raised from its seat, water enters the trapping-box, and air is forced up the escape pipe to be discharged over the surface of the water in the cistern. Now the supply-pipe and trapping-box are always full of air, which ascending from the closet basin is very liable to be foul, and it is this air which escapes over the water of the cistern, and may impart to it disease producing qualities. The contagia of the infectious diseases are probably particulate organisms which may be held suspended in the air of drains and sewers, and are liable in this way to be brought into contact with water. But water is also capable of dissolving foul gases in contact with it, and it is this property which often imparts such an offensive smell to the water of cisterns supplying pan closets, or with overflow pipes connected directly with D traps or soil-pipes.

Hopper water-closets are often found to be supplied with water direct from the house main. During an intermittence of the water service, the tap may be left open, and foul air or liquid filth may at such times be sucked up from the closet basin into the water pipes. Several severe epidemics of enteric fever have been traced to this cause.

Sewers.

Sewers are underground channels designed to receive and convey away by gravitation the rainfall and waste waters of the town, and where the water-carriage system has been adopted, solid excretal refuse as well. In former times, and in some towns at the present day, as at Dublin, if a river or stream passed through or near a town, the sewers took the shortest available course to the banks of the stream and there discharged—each sewer by its own outfall. When it became no longer possible for towns to discharge their crude sewage into streams in this manner, intercepting sewers of large size had to be constructed to receive the sewage of the tributary sewers; and these intercepting sewers, when united to form one or more main outfall sewers, conduct the sewage outside the town, there to be discharged into the stream in its crude state, or after it has undergone some process of purification.

As we have already seen, brick sewers as originally constructed, perform a double function; they are drains as well as sewers; for not being constructed watertight they drain the soil by admitting subsoil water, and they may also be used to convey away the sewage. By permanently lowering the level of the subsoil water in towns, these sewers had an important effect in improving the health of the inhabitants. Dr. Buchanan in his well-known Report (9th *Report of the Medical Officer of the Privy Council*) has shown, that the effect of drying the soil, in the case of towns where the level of the subsoil water was previously high, was to greatly diminish (by $\frac{1}{3}$ to $\frac{1}{2}$) the death-rate from phthisis. The connection between phthisis and moisture in the soil, which had been previously pointed out by Dr. Bowditch of Massachusetts was thus confirmed by Dr. Buchanan; and this discovery is one of the most interesting and most important, in its bearing on the public health, in the whole range of sanitary science.

But the beneficial influence of sewers acting as drains has an undoubted drawback, viz., that drain sewers will just as readily permit of foul liquids percolating out of them through their walls to pollute the surrounding soil and contaminate ground water and ground air in the neighbourhood, as of subsoil water entering them.

That such escape of foul water does take place, is plainly shown by the fact that in London with its drain sewers all shallow well-waters have been found to be polluted with sewage, and the wells have in consequence been closed. The pollution of the ground air has also an important bearing on health, as such air is liable to be drawn into houses, whose basements are not thoroughly concreted over. It is now the practice of all engineers to construct sewers as far as possible water-tight, and to provide other means for draining the soil. The drainage of the subsoil, being so important a consideration from its bearing on the public health, must not be lost sight of in those towns which by reason of a low situation, or an impervious subsoil, have the underground water but a few feet from the surface.

The combined system.—In this system, the sewers are designed to receive the rain—or such part of it as does not evaporate or sink into the soil—falling over the area covered by the town, as well as the sewage proper. The amount of evaporation depends largely on the temperature of the air; but even in summer it is found in towns, where a large part of the surface exposed to rainfall consists of roofs and paved surfaces of yards, courts, and streets (especially also where there are steep gradients), that from one-half to three-quarters of the rain falling reaches the sewers. It is therefore necessary to construct the sewers large enough to take a large part of the rain falling during heavy storms, such as $\frac{1}{4}$ inch of rain in 2 or 3 hours or less; otherwise, if no storm overflows are provided, the sewers in low lying districts are overcharged, and cellars and basements are flooded. In London the intercepting sewers were constructed to receive $\frac{1}{4}$ inch of rain over the whole area sewered in 24 hours (including subsoil water); but storm overflows direct into the Thames relieve these sewers during heavy storms. When a storm occurs after a time of drought, the sewers are flushed of accumulated deposit, and the sewage which escapes by the storm overflows is often very strong and foul, and productive of nuisance in the river. At high water the storm overflows are tide-locked and then low-lying districts may be flooded.

To prevent deposit, sewers should be rendered self-cleansing by being constructed with a sufficient gradient, and of a size suitable to the volume of sewage which they will ordinarily be required to carry. According to Mr. Baldwin Latham, sewers of from 12 to 24 inches diameter should have a gradient sufficient to produce a velocity of not less than $2\frac{1}{2}$ feet per second, and in sewers of larger dimensions in no case should the velocity be less than 2 feet per second. For large sewers a less gradient is required than for small sewers to produce the same velocity; but the volume of the sewage to be conveyed must be very much greater for the large than for the small sewer. A sewer 10 feet in diameter having a fall of 2 feet per mile; a sewer 5 feet in diameter having a fall of 4 feet per mile; a sewer 2 feet in diameter having a fall of 10 feet per mile; and a sewer 1 foot in diameter with a fall of 20 feet per mile, will all have the same velocity, but the volume of sewage in the 10-foot sewer must be 100 times, in the 5-foot sewer 25 times, and in the 2-foot sewer 4 times the volume of sewage in the 1-foot sewer.

To calculate the discharge from sewers the following formula is generally used.

Let V = velocity of flow in feet per minute.
,, D = hydraulic mean depth.
,, F = fall in feet per mile.

Then $V = 55\,(\sqrt{D \times 2F})$.

If A = sectional area of current of fluid, V × A = discharge in cubic feet per minute. The hydraulic mean depth is one-fourth the diameter in circular pipes; in pipes other than circular, it is the sectional area of the current of fluid ÷ the wetted perimeter (that part of the circumference of the sewer wetted by the fluid flowing through it).

In modern systems of sewerage, the sewers are laid in straight lines with manholes at every point of change of direction. The inspection and cleansing of the sewers is much facilitated by such an arrangement. The best form of sewer in all cases in which the volume of sewage undergoes fluctuation, is the egg-shaped; the small end of the egg downwards. In this form, there is a greater depth of sewage and less contact with the walls of the sewer, and consequently less friction, than in any other form. For outfall sewers, in which the volume of sewage to be conveyed is large and uniform, Mr. Baldwin Latham advises the circular form, as it is cheaper and stronger when constructed. Up to 18 inches internal diameter, sewers should be circular in section; and for these small sizes stoneware, cement, or concrete pipes are better than sewers constructed of brick. Mr. Latham's experience is that no public sewer should be less than 9 inches in diameter, owing to the risk of smaller pipes becoming obstructed and stopped up by articles improperly introduced into the house drains.

Well-burnt, tough, impervious bricks, or glazed fire-bricks should be used in the construction of sewers; especially in the construction of the lowest segment or invert of the sewer, which is the part most liable to wear and erosion from the passage of the suspended matters in the sewage over it. For the smaller sewers suitably curved bricks only should be used. Sewers under 3 feet in diameter, when laid in good ground, may be constructed of $4\frac{1}{2}$-inch brickwork. When laid in bad shifting ground, or for larger sewers, 9-inch brickwork should be used. Suitably curved stoneware blocks are now very generally used for the inverts of sewers; their smooth hard upper faces form an excellent floor for the sewer. When these blocks are made hollow, they provide a means of draining off the subsoil water during the construction of the sewer; but engineers advise their being filled in with concrete at the completion of the works, as the hollow block is apt to split from the weight of the sewer built over it. The mortar used in joining the bricks should be made of the best Portland cement and fine sharp sand. Portland cement is a mixture of chalk and clay burnt at a high temperature, and subsequently ground very fine. It is stronger and capable of bearing greater tensile strains than other cements (Roman and Medina), but does not set so rapidly.

The Separate System.—Where it is intended to convey away sewage proper only, storm, surface, and subsoil waters being excluded, the sewers need be only of small size. Under such circumstances glazed stoneware pipes, jointed with Portland cement, are generally used to form the tributaries whilst the outfall sewer is constructed of brickwork. Cement or silicated concrete pipes have been used, especially in Germany, instead of stoneware pipes. They are said to be less brittle, to withstand extremes of climate, and to resist the chemical action of the sewage better than stoneware pipes. The sewers, of whatever material, must receive water-closet sewage and waste waters only; all rain water from roofs, yards, or areas, must be conveyed by separate pipes into surface channels at the sides of the streets, when the gradients are sufficient, or into underground channels constituting a system of drains quite distinct from the sewers. At convenient points the surface channels or underground drains should discharge into the stream or river, which forms the natural drainage bed of the locality. The drainage of the subsoil should be effected by agricultural tile drains laid in the same trench but above the sewers, and diverted into the water-courses at all suitable points.

The advantages of the separate system are (1) the volume of sewage to be conveyed outside the town is small as compared with that to be dealt with by the combined system; its daily or seasonal fluctuations, and the total quantities to be dealt with, can be calculated approximately from the population and water supply (points of great importance where the sewage has to be pumped to the outfall, or purified before being discharged); (2) the sewage is uniform in composition because protected from dilution with storm waters, and its purification and utilisation are undertaken with much less difficulty than is the case with sewage which is sometimes strong, and at others very weak, from admixture with rain and subsoil waters; (3) the sewers being small and having smooth walls, are more frequently flushed, and there is less tendency to deposit, with formation of foul gases, than in the case of the larger brick sewers; (4) the cost of the system is very much less than that of the combined system.

The disadvantages are, (1) that every house must have two drains or two sets of pipes—one for sewage and the other for rain water; and this gives rise to mistakes on the part of builders, who occasionally connect the pipes with the wrong system; (2) that the surface water from yards and streets is often foul, especially when a storm succeeds a period of drought, unless the yards and streets are constantly cleansed and well scavenged. It is, however, sufficiently obvious that these obstacles can be overcome, and in no way counterbalance the undoubted advantages of the separate system.

Junctions between pipe sewers should be made by properly curved pipes, as explained under house drains. Where two or more tributary sewers join a main sewer, a manhole should be built over the point of connection, with curved channels in its floor for the connecting pipes.

Inspection, Flushing, and Ventilation of Sewers.

In any system of sewerage it is necessary to provide means of access to the sewers for their cleansing and for the removal of accumulations of deposit. Manholes are shafts sunk from the surface of the road to the sewer, by which the scavengers can descend. They are constructed of brickwork and provided with a locked iron door at the street level. In streets where there is much traffic, the shaft is sunk from the footway perpendicularly for a short distance, and then carried down by means of steps to the side of the sewer. In other cases the manholes are sunk from the middle of the road to the crown of the sewer. They have also a variety of other uses: they are used as points of junction between tributary sewers and the main sewer, curved channels being constructed in the floor of the manhole; and they are also the points at which flushing-gates may most advantageously be fixed in brick sewers.

Flushing-gates are sluices made to fit the whole or part of the sectional area of a sewer. When in position they dam back the sewage in the sewer above, and on being raised, or liberated, the sewage so stored rushes forwards and effectually flushes the sewer below. Self-acting gates are often used for this purpose. The gate being hinged below its centre, the pressure of the sewage on that portion of the gate which is below the hinge, fixes it in position. As the sewage rises, the upper portion of the gate is likewise exposed to the pressure of the sewage, and presenting a larger area than the part below the hinge, a point is at length reached when the gate tilts, assuming a horizontal position, and the sewage escapes. Flushing-gates are not used for flushing the upper ends of brick sewers, nor are they used for flushing pipe sewers. For these purposes, automatically discharging siphon flush-tanks find a most useful application. They should be supplied with water from a tap connected with the town water-main, and regulated to discharge at intervals as required.

It might be thought that the pipe sewers used with the separate system do not require artificial flushing. But experience has taught otherwise, and it must be remembered also, that under this system the sewers are not flushed by storm waters. There can be no doubt that heavy rainfall is very effectual in flushing sewers; but besides introducing a quantity of grit and sand from the roads, rainfall cannot be depended upon in this climate to occur at properly recurring intervals, and is often absent for long periods in summer when sewer deposits are most abundant and most offensive.

Town sewers are underground channels which form air communication shafts from one house to another, in all cases except where a house drain is disconnected from the sewer by a water-trap and opening to the external air. Disease poisons excreted in one house may at any time pass by means of this aerial connection into the drainage pipes of another house in its neighbourhood or remote from it. It is impossible for anyone, whether he be chemist, biologist, or physician, to determine when sewer air is free from disease poisons and when it is not; hence the acknowledged necessity of preventing any entrance of drain or sewer air into houses, and the universal adoption by competent authorities of some means of ventilating drains and sewers, and of giving exit to the mixed air and gases at a point as remote as possible from dwellings.

The *ventilation of sewers* is therefore a matter of the greatest importance, as the health of a sewered district largely depends on the efficiency of the sewer ventilation. The poisons or infective agents of cholera and typhoid fever, and of certain forms of dysentery and diarrhœa, are contained in the discharges from the bowels of the patients suffering from these diseases; and on reaching the sewers it is now generally believed that such discharges may impart their infective qualities to large volumes of sewage, and to the deposits and slime which are so frequently found on the floors and walls of the sewers. There can be little doubt too that the air in contact with such infected materials also becomes imbued with specifically contagious properties. The infective material is in all probability—although actual demonstration is still wanting—due to active living organisms or their germs of the class bacteria, which after evacuation from the body of the patient find a suitable soil for growth and propagation in sewage and sewer deposits.

The mode in which sewer air becomes infected is not known; but it is probable that during evaporation, or from the bursting of bubbles of gas when the sewage is putrefying, suspended matters, amongst which may be the particulate organisms of disease, are projected from the liquids into the air in contact with them, in which they float until the air becoming stagnant, they tend to subside. On some such hypothesis as this, we can account for those epidemics of enteric fever which have undoubtedly been caused by inhaling sewer air, or by contamination of drinking water in cisterns and mains by such air. Acute sore throat and diphtheria have also been caused by vitiation of the atmosphere with sewer air, and it is a remarkable fact that in General and Lying-in Hospitals, in which the air of the wards was liable to pollution with drain and sewer air, surgical fever, erysipelas, pyæmia, septicæmia, and puerperal fever, were very prevalent and very fatal; but after measures had been taken to improve the drainage and sewerage of these institutions, and prevent any possibility of foul air gaining access to the wards, such diseases very greatly diminished, and in some cases totally disappeared.

We must bear in mind also that sewage contains the water used for washing clothes from patients suffering from other infectious diseases as small-pox, scarlet fever, and measles, and may therefore at any time contain the specific poisons of such diseases. As regards the possible spread of these diseases by infected sewer air, we at present possess no definite proofs of such an occurrence ever having occurred, however probable we might think it to be.

Chemical examination shows that sewer air is subject to wide variations. A sample of air taken from a choked sewer in Paris was found by Parent Duchatelet to contain only 13·79 per cent. of oxygen, and as much as 2·99 per cent. of sulphuretted hydrogen. The air of closed cesspools in Paris must often have been quite as deficient in oxygen to have caused those symptoms of partial asphyxia from which the workmen, employed to empty them, occasionally suffered.

Where the quantity of sulphuretted hydrogen has been very great, sudden death has in some instances resulted amongst those who opened the cesspool.

In the London sewers the air is very much purer. The most impure sample taken by Dr. Russell from the Paddington sewers was found to contain 0·51 vols, CO_2, 20·7 vols. O, and 78·79 vols. N in 100 vols. In so far as these constituents are concerned, this air is not very much more impure than that found in crowded dwelling rooms, but then the London sewers are comparatively well ventilated. The most offensive gases are given off from sewers in which deposit forms, such as the old-fashioned brick conduits with flat bottoms, or oval sewers in which a portion of the invert has sunk below its proper level, or sewers which are too large for the volume of sewage they ordinarily convey, and in which the deposits and slime, formed on their floors and sides, are not removed by flushing. Outfall sewers in which sewage is, for any reason, backed up and stagnant during a portion of the day, are also liable to become sewers of deposit. The deposit rapidly putrifies, giving off offensive gases, which escape through the nearest ventilator, or should the sewer be insufficiently ventilated, the foul gases find an exit through house drains and traps into the interior of houses.

It is probable that sewage which has become specifically infected with enteric fever evacuations is quite as dangerous when fresh and undecomposed, and therefore little offensive, as when it is undergoing fermentation and putrefaction. An epidemic of this disease at Croydon in 1875 was traced by Dr. Buchanan to the entry of air from unventilated pipe sewers into the houses of those attacked. The sewage was carried away by these pipe sewers in a fresh and undecomposed condition, and Dr. Buchanan expressed at that time the opinion that "the material of contagion is perhaps less likely to be active in excrement that has passed into fœtid decomposition." On the other hand, air in contact with putrid sewage contains a far larger proportion of suspended organic matters—amongst which may be floating the particulate disease organisms —than air over fresh sewage, and in numerous recorded epidemics of enteric fever due to sewer air escaping from foul unventilated sewers, we find the exhalations were most offensive, showing that the sewage was in a putrid condition.

In all sewers, owing to the constant variation of the flow of sewage through them, some deposit forms on their sides, which being alternately wet and dry, rapidly putrifies, and parts with its putrefactive ferments to the sewage flowing by. A deposit of sewer slime from the Liverpool sewers was found by the late Prof. Parkes and Dr. Burdon Sanderson to contain ammonia, nitrates, and large quantities of fungi and bacteria. That sewage as well as slime deposit may form a favourable soil for the growth and germination of such disease organisms, as are capable of existing outside the animal body, is highly probable, when we consider that sewage contains organic matters of animal and vegetable origin, phosphates, and ammonia, all affording food for the growth of microbes which is likewise aided by the warmth of the sewage and the darkness of the sewer. In pipe sewers there is less tendency to deposit than in brick sewers of larger diameter, owing to the smooth internal surfaces of the pipes, and to the greater frequency with which they are washed, as pipe sewers are more often running full or nearly full than brick sewers.

Natural ventilation of sewers, by which movements of air in them are produced, is due to a variety of causes, the most important of which are:—(1) where there is a strong and rapid stream, a current of air is produced which is in the same direction as the sewage stream, and of proportional velocity. Most of the openings into the sewers will be inlets for fresh air, drawn in by the current of air beneath, which finally escapes through the outfall sewer. (2) During the cold months of the year, the temperature inside a sewer is, owing to the warmth of the sewage, higher (average about 7° F) than that of the external atmosphere, consequently the warmer sewer air tends to rise and be replaced by the cold external air. During the warm months of the year the temperature of the sewer is by day often considerably cooler than the external air. In spring and autumn the temperatures inside and outside are more nearly equal. (3) The passage of hot liquids from houses and from factory boilers causes a rise in the temperature of the sewage and expansion of the sewer air. Blowing off steam from boilers into sewers causes a great rise of pressure, and unless ample ventilation is provided, house traps will be forced. (4) During the early part of the day, the volume of sewage in the sewers increases rapidly to a maximum, and air is consequently slowly expelled to be replaced by inflowing air as the volume of sewage decreases. The rising of the tide in an outfall sewer, not protected by a tidal valve, will also displace air, but the displacement is so gradual as to be almost inappreciable. Where storm-waters are admitted into the sewers, sudden heavy rain-falls exert a marked influence in expelling air, which is somewhat counterbalanced by the aspirating effect produced by the flow of air in the direction of the current. (5) Sudden falls of barometrical pressure cause air and gases dissolved in the sewage to be given off. (6) Sudden variations in temperature of the external air produce variations in pressure of the sewer air. A high temperature favours decomposition of the sewage and evolution of gases.

Openings into the crowns of sewers from the surface of the roadway should be made at distances of not more than 100 yards apart. Some of these will act as inlets and others as outlets, and the pressure of air in the sewer will at no time be able to rise sufficiently to force the traps on house pipes and drains. Where the sewers are insufficiently ventilated, or where the openings are blocked with clogged charcoal trays, sewer air will find its way past the iron flap-valves usually placed so as to cover the openings of the house drains into the sewer; and if there is no disconnection trap on the house drain, such air will escape into the house through defective joints in the drain or soil-pipe, through bell-traps in the floor or on waste pipes, or by means of the overflow pipe from the cistern will cause a very dangerous pollution of the water. The warmth of the interior of inhabited houses, and the draught produced by fires tend to exert a distinct aspirating action on the colder and heavier sewer air "laid on," so to speak, by a system of pipes to all parts of those houses, in which no disconnection apparatus at the foot of the house drain has been fixed.

It is true that, in such cases, sewer air can usually readily escape by means of rain water pipes from the roof, directly connected with the drain; either through the loose joints between the different lengths of pipe (often close to windows), or at the head of the pipe which may be directly under an attic window. During heavy rain too, the falling water will force the confined air through trapped or untrapped openings into the house.

The same objections apply to the method of ventilating sewers by means of the soil-pipe ventilators of houses. It may be safe so long as every joint on drain or soil-pipe, and every trap on waste pipes and W.C.'s, is sound and in good order; but directly a defect arises, it may be the means of providing an escape into the house of possibly infected sewer air. Where a disconnecting trap is fixed on the house drain, a 4″ pipe may be carried up to the ridge of the roof from the drain on the sewer side of the trap, its end being left open; and it will be found useful as an exit for sewer air when used in combination with road ventilators. But it is needful to bear in mind that where rain water is admitted to the sewers, during heavy rainfall, when ventilation is most required for affording a safe exit for suddenly displaced sewer air, house drains or any part of them are often useless for this purpose, as their openings into the sewer may be sealed by the height at which the sewage is flowing in the sewer.

The best form of street ventilator is a shaft sunk from the middle of the roadway to the crown of the sewer. Beneath the grating at the surface of the street should be placed a dirt-box to catch gravel and mud, which would otherwise fall into the sewer; a space being left around the box for the passage of air. The dirt-box should be capable of removal from the surface of the road. Ventilators may also be constructed in conection with manholes. A shaft is sunk for a short distance by the side of the manhole, openings being made between them for the passage of air. Mud and gravel fall to the bottom of the shaft, from which a pipe conducts the water to the sewer beneath. The air which escapes from the sewers by these street ventilators is rapidly diluted with fresh air; and from their position in the centre of the roadway, there is the least chance of offence to foot-passengers or of foul air gaining entrance to houses. In narrow courts and streets, especially at the upper or dead ends of sewers, these surface ventilators should be replaced by shafts carried up from the crown of the sewer to the tops of houses; for it is desirable to avoid any risk of foul sewer air collecting in stagnant courts or streets surrounded by buildings, in which rapid dilution of the sewer exhalations with fresh air might not always take place. Street gullies should be effectually trapped, both to prevent mud and sand entering the sewers, and to avoid an escape of sewer air close to the footways and the fronts of houses.

Iron-wire baskets containing small wood charcoal were, at one time, extensively used to filter the air escaping through the ventilators. When dry, they exercise considerable influence in oxidising and deodorising organic vapours. But they rapidly become wet from rain and moisture, and then they are not only useless as deodorisers, but the pores are so clogged as to obstruct all passage of air through them. For these reasons their use has been nearly everywhere discontinued.

Where sewers are laid with steep gradients, it is found that a current of air tends to pass, in the reverse direction to the flow of sewage, from the low to the high levels. To prevent the escape of large volumes of foul air at the upper parts of a sewered district, it is necessary to construct at various points a tumbling bay with manhole and ventilator above, a flap-valve being applied to the mouth of the sewer delivering sewage over the tumbling bay. Then the sewer air in its course upwards, meeting the flap-valve, is forced to escape into the outer air through the ventilator.

It was at one time thought that by connecting sewers, by means of shafts, with a furnace chimney, a powerful extractive force, useful in ventilating a large portion of the system, would be put in operation. By this method, however, a great draught for a short distance only is produced, as air rushes in from all openings in the neighbourhood to supply the place of that extracted by the furnace. Beyond a very short distance no effect is produced, and there is besides considerable risk of traps in houses being drawn.

Adequate ventilation is just as necessary for pipe sewers as for brick sewers. The experience at Croydon is sufficient proof of this. In his report on the epidemic of enteric fever at Croydon in 1875, Dr. Buchanan says, "To some extent when sewers are running freely, but greatly more when they are not running freely, displacement of air from them is an affair of sewer calibre." Displacement of air from the entry of a volume of water will be 16 times greater in a 6-inch sewer than in a 2-feet sewer, and the displacement will be greatly more sudden. "Hence the air in a small sewer is liable to be under far greater pressure than the air in a large sewer." Numerous openings into the outer air must exist for the exit of this displaced air, or it will find its way into houses through trapped and untrapped pipes.

Outfall Sewers.—In some cases it may be necessary to carry the sewage of a town across a river or a valley. This may sometimes be done by bridging; but usually the outfall sewer is at too low a level to permit of it. In such cases the sewer should be carried across by means of an inverted siphon, formed of wrought-iron pipes with rivetted flange joints, laid in the bed of the river or valley. Arrangements must be made for preventing the accumulation of solid matters at the lowest point of the siphon, resulting eventually in a stoppage, to which there is a tendency, unless the current through is of sufficient velocity to carry all solid matters with it. With this view the sewage may be strained before passing through the siphon, or the siphon must be periodically flushed. To give exit to air under pressure in the siphon, which might prevent its proper action, a ventilating pipe should be attached to the descending arm.

The Disposal of Sewage.

The disposal of the sewage of a town or district is always a matter for careful inquiry and consideration. It is usually the most difficult problem to solve of any connected with the sewage question. Fortunately since the Rivers Pollution Prevention Act became law in 1876, the nature of the problem has been altered. The question for a local authority to determine is now, not How to get rid of its crude sewage with the least trouble and expense, but, How to purify the crude sewage so that it may be admissible into a stream. For the Rivers Pollution Prevention Act made it illegal to discharge crude sewage into a *stream;* this term including rivers, streams, canals, lakes, and watercourses, other than watercourses mainly used as sewers, and also the sea, to such extent, and tidal waters to such point, as may after local enquiry, or on sanitary grounds be determined by the Local Government Board. It is greatly to be regretted that this act has, in many parts of the country, entirely failed to prevent the continued pollution of streams, by which the community has already so largely suffered. The interests involved in the continuance of the existing state of things were, and are, too great to be set aside to benefit merely the health and comfort of the people. The crude sewage and waste refuse of most of our northern manufacturing towns still pollute the streams and rivers as of yore.

The evils that result from the discharge of crude sewage into the estuaries of rivers, are exemplified in the case of the discharge of the crude metropolitan sewage into the Thames at Barking and Crossness. It is true that in this case the volume of sewage discharged is enormous—about 150 million gallons daily—and it has even been calculated that, during very dry weather, the sewage in the neighbourhood of the outfalls forms one-sixth of the whole volume of the river water. But even if the volume of sewage were very much less, there are certain circumstances in connection with tidal rivers, which are adverse to, or retard that process of self-purification by dilution and oxidation, by which only can a nuisance and danger to health be overcome.

Where sewage is discharged into fresh running water and at once largely diluted, it becomes in course of time to a great extent purified. Distributed through a large volume of clean water, the organic matters are oxidised by the oxygen dissolved in the water, and by that given out by minute water plants (Algæ, Diatoms, and Desmids), and are assimilated by minute animals

(Infusoria, Rhizopoda, Entomostraca, Anguillulæ, etc.). They are thus purified, or got rid of, without the occurrence of putrefaction and the formation of offensive gases, which must occur when the sewage is not sufficiently diluted with fresh water and the temperature of the air is high; the growth of bacterial organisms then taking place to such an extent as to cause putrefaction. Putrefactive bacteria will no doubt, in time, break up complex organic matters into their constitutent parts, and thus purify sewage; but the process is one productive of nuisance and injury until the ultimate effect is produced.

In the case of tidal rivers, the Reports of the Royal Commission on Metropolitan Sewage Discharge show that there may be a considerable concentration of sewage in the river, forming what has been termed a "sewage zone," due to the oscillation of the tides; for the river water into which the sewage is discharged is not pure water, but is water that by reason of the tidal oscillations has already become contaminated by the accumulation of successive previous sewage discharges. The only true sources of dilution are the land water entering from above and the sea water from the mouth of the river. During dry weather when the quantity of land water is slight, the displacement of the sewage towards the sea is very slow (about ¼ mile daily in the case of the metropolitan sewage); so that the sewage discharged on any particular day oscillates up and down the river with the tide, and is continually receiving fresh increments of sewage. The sewage too that is discharged after high water will be carried up by the flowing tide above the outfall; and when neap tides are giving place to spring tides, the whole volume of discharged sewage is carried up higher and higher above the outfalls every day as the spring tides increase. The consequence is that at such times the sewage may be carried in the river up to or above the town so discharging its sewage.

The effect too of the sea-salts in estuary water is to cause a precipitation of organic matters, and a deposit of mud, whilst the oxidation and purification processes are delayed by their presence.

On the whole then we see how erroneous is the idea that sewage, discharged into the tidal water of a river, is at once carried out to sea. What really takes place is very different, and the sewage is even at the best of times but slowly borne out to sea. In the case of tidal rivers, as in those portions of a river which are beyond the reach of the tide, the purification of the sewage without nuisance, must always be a question of dilution. If the volume of sewage discharged is relatively small to the volume of water in the river, the sewage will in time be purified; but such water can under no circumstances be a proper source of supply for drinking water. If the relative proportions of sewage and river water are the same, the non-tidal river possesses great advantages over the tidal; for the sewage is at once carried away, and cannot return above the outfall, whilst the purifying processes are not hampered by the presence of sea-water.

Under certain circumstances sewage may be discharged into the sea without risk of nuisance and offence. If the sewage can at all times be borne away from the shore out to sea, it becomes mixed with an immense volume of water and rendered harmless. The danger is, lest sewage should be cast up by the tide on the fore-shore, or borne along by currents the whole length of the sea-front of a town. To avoid such an event, the outfall must be chosen at such a spot that the sewage, at whatever state of the tide it may be discharged, shall be carried by currents, where such exist, straight out to sea, or at least in a direction away from the town.

The outfall sewer must open below the level of the water at all states of the tide, and its mouth should be protected by a tidal valve to prevent sea-water entering it. The prevailing winds should also be studied, to prevent the possibility of floating fæcal matters being blown back on to the beach. If the town lies at a low level, so that its sewers are tide-locked for several hours of each tide, tanks must be constructed to retain the sewage which accumulates at such periods; or a certain length of oval tank sewer must be built for the same purpose. In other cases pumping is had resort to, or Shone's Pneumatic Sewage Ejectors may be used.

All sewage cast into the sea is inevitably wasted; for although Sir John Lawes has expressed the opinion that sewage is "utilised to a certain extent by the fish feeding upon that which the sewage produces," viz., minute forms of animal and vegetable life; yet it has been pointed out by Professor Huxley that our great sea fisheries are inexhaustible, and that nothing man can do can seriously affect the number of fish in the sea. Even then did the fish benefit by the sewage poured into the sea—an assumption that has not yet been proved—we should be supplying them with a material, which they could well do without, and which could never bring any return in the shape of larger takes of fish.

The Purification and Utilisation of Sewage.

It can safely be said that in this country no stream or river should ever receive crude sewage; for so numerous are the towns on the banks of nearly every stream, that although the sewage of one town might be purified after a certain run, it would be quite impossible for any stream to purify the successive sewage discharges from every town on its banks. As the sewage must be purified before discharge, the question arises whether it can at the same time be utilised, and made to pay the whole or part of the expenses incurred in its purification. It becomes necessary then to consider the amount and value of the manurial ingredients contained in ordinary town sewage.

In the first place as to the chemical composition of sewage. The Rivers Pollution Commissioners give as the average in water-closeted towns, in 100,000 parts, 72·2 of total solid matters in solution, in which there are 4·696 parts of organic carbon; 2·205 of organic nitrogen; 6·703 of ammonia; total combined nitrogen 7·728; chlorine 10·66; and an inappreciable quantity of nitrogen as nitrates and nitrites. In 100,000 parts there are besides 44·69 of suspended matters, of which 20·51 are organic, and 24·18 mineral matters. This is an average from a large number of analyses; but it must be borne in mind that the sewage of different towns varies greatly in character, and that the sewage of the same town varies in strength from day to day and from hour to hour. To obtain an exact knowledge of the average strength of a day's sewage in any town, samples must be taken frequently—at least every hour—and if two or more samples are mixed to form a sample for analysis, they must be mixed in such proportions as are indicated by guaging the flow of sewage at the time each sample was taken. In this way only can the average composition of the sewage be arrived at with anything like exactitude.

The strength of the sewage depends on the number of water-closets in a town (proportion of W. C's. to middens), the amount of water supply per head of the population, the amount of waste liquors discharged into the sewers from manufactories, and, in the case of drain-sewers, the amount of rain that has fallen, and of subsoil water that has found its way into them. During the early part of the day the sewage of any town is strongest, and the flow greatest, whilst at night the sewers may be discharging nothing but subsoil water. It is thus seen that the average yearly composition of the sewage of any town can only be determined by such analyses, as we have above indicated, carried on through every day of the year. This average composition, when determined, may differ very much from the average given by the Rivers Pollution Commissioners, and the average value of a ton of such sewage will differ also, for the greater the dilution the less the value.

The chief valuable ingredients of sewage are the different forms of combined nitrogen, the phosphates, and salts of potash. The money value of these constituents in 100 tons of the sewage of the strength noted above is 17*s.*; the dissolved matters being worth 15*s.*, the suspended 2*s.* This gives a value to the sewage of about 2*d.* per ton. We have already seen that the yearly excretal refuse of an individual of a mixed population is worth from 6*s.* 8*d.* to 7*s.* (see p. 91), and this refuse, if diluted with water to form 40 tons of sewage (an average dilution of 24 gallons per head per day), will also give a value to the sewage of 2*d.* per ton. This dilution is about that of the London sewage during dry weather. It may further be stated that 855 tons of the sewage of the composition given by the Rivers Pollution Commissioners, contain one ton of solid matters (in solution and in suspension) estimated to be worth £7 5*s.* 4*d.* From such data as these, calculations might be made of the total yearly value of the sewage of any town. But such theoretical calculations may be very far from representing the real practical value.

The composition of sewage from midden towns (see p. 92) does not differ very materially from that of water-closeted towns. The Rivers Pollution Commissioners gave as the average composition of midden town sewage in 100,000 parts: total solids in solution 82·4; organic carbon 4·181; organic nitrogen 1·975; ammonia 5·435; nitrogen as nitrates 0; total combined nitrogen 6·451; chlorine 11·54; total solids in suspension 39·11, of which 21·30 are organic matters, and 17·81 mineral matters.

Subsidence, Straining, and Precipitation.

By allowing sewage to settle in tanks, a portion of the suspended matters subsides to the bottom, and a more or less clarified liquid can be decanted from the top. By straining sewage through beds of ashes or charcoal, the suspended matters are removed; but the filters speedily become clogged and require frequent renewal at great expense.

Certain chemical substances, when mixed with sewage prior to its entering settling tanks, cause a more rapid and copious precipitation of the suspended matters than can be effected by subsidence alone. The number of chemicals that have been used or advocated for this purpose is enormous, as may be seen on inspection of the specifications of patents taken out to protect the inventors of such processes. Practically only three substances are now in use as chemical precipitation agents, the others having either proved worthless or too expensive for general use. Lime—as lime-water or milk of lime—sulphate of alumina, and protosulphate of iron, are the substances now used as precipitation agents, either singly or in combination.

The precipitating effect of lime on sewage is due partly to its combination with free and partially combined carbonic acid, forming an insoluble carbonate of lime, and partly to its combination with some of the organic matters of sewage. These substances subside, carrying with them the whole or a part of the suspended matters in the sewage, and sink to the bottom of the tank, forming the sludge; whilst a more or less clear liquid, the effluent, remains above. If too much lime is added, the sludge and effluent being alkaline, tend soon to undergo fermentation and decomposition. The proportion of lime most usually added to the sewage is fifteen grains to the gallon of sewage for milk of lime (lime slaked with water), and from three to five grains to the gallon for lime water (lime dissolved in water).

The precipitating effect of sulphate of alumina on sewage is due to combination of the sulphuric acid with lime and other bases in the sewage, whilst the alumina hydrate is precipitated in a flocculent condition, entangling and carrying down in its course most of the suspended organic matters. The crude sulphate of alumina used as a precipitant is acid, so that the effluent and sludge are rendered slightly acid by treatment with this substance alone. An acid effluent is less prone to decompose than an alkaline; but should it be desired to irrigate land with the effluent after leaving the tanks, acidity would be harmful because injurious to vegetation. The best chemical authorities now recommend the use of lime with sulphate of alumina for precipitating sewage; the proportions in which they are used being such as to render the effluent as nearly neutral as possible. For treating sewage of medium strength the quantities need not exceed five grains of lime, and five grains of sulphate of alumina, per gallon of sewage.

When protosulphate of iron is added to alkaline sewage or to sewage which has been already treated with lime, a highly flocculent hydrated protoxide of iron is formed, which falls to the bottom of the tank, carrying suspended organic matters with it. The iron salt is also a powerful antiseptic, preventing further putrefaction of the sludge and effluent, when used in sufficient quantity. But its use is attended with the disadvantage that the mud-banks of the stream, into which the effluent is discharged, are blackened by the formation of sulphide of iron—a somewhat sentimental disadvantage, but a very real one. When used with lime, protosulphate of iron should be added in the proportion of from two to five grains per gallon of sewage.

These three precipitating agents—lime, sulphate of alumina, and protosulphate of iron—cause a more or less complete deposition of the suspended matters in sewage, and thereby remove the grosser sewage odour from the effluent; but they have very little, if any, effect in removing from the sewage the organic matters in solution, and they leave quite untouched the ammonia, which, together with the soluble organic matters, escapes in the effluent. Sulphate of alumina is said to have the effect of removing five per cent. of the dissolved organic matters of sewage, but lime and iron remove none. It follows then that the matters precipitated from sewage, which form the sludge at the bottom of the tanks, are comparatively worthless, whilst the bulk of the valuable manurial ingredients remain in the effluent.

To ensure the most complete clarification of the sewage liquid by chemical precipitants, the following conditions must be satisfied. The sewage must be fresh and undecomposed. The chemicals must be added to the sewage before it arrives at the tanks, and must be well stirred and mixed up with it by means of rotatory beaters. There must be sufficient tank accommodation. The treated sewage should flow into two subsiding tanks arranged in series; the first capable of holding 1 hour's flow, and the second not less than 4 hours' flow. These tanks must be at least 4 feet deep, and the effluent passing out should flow over a weir not more than ½ inch below the surface. There should be a double set of tanks, in order that the treatment of the sewage may continue, whilst the sludge is being removed. The sludge must be frequently removed or it will putrefy, and black masses will be disengaged, which, rising to the surface, give off foul gases. The tanks, when emptied, must be thoroughly cleansed before being refilled.

Occasionally substances, which act as deodorants or antiseptics, are added to the sewage as well as the chemical precipitants. Amongst these we may mention Black-ash waste (Hanson's process), used in conjunction with lime. Black-ash waste is prepared from the refuse of alkali works, that has been long exposed to the air, and contains hyposulphites and sulphites of lime, which are powerful reducing or deoxidising agents. Black-ash waste has considerable deodorant and antiseptic properties, and has proved of service in mitigating the pollution of the river Lee—the sewage of both Tottenham and Leyton being now treated by Hanson's process. The addition of manganate of soda and sulphuric acid to chemically treated sewage has been recommended by Mr. Dibdin, Chemist to the Metropolitan Board of Works. These bodies act as oxidation agents.

In the "A.B.C." process now carried on at Aylesbury by the Native Guano Company, alum, blood, clay, and animal and vegetable charcoal are added to the sewage. The effect of the blood is not known, and in the small quantities used is probably *nil;* the clay acts as a weighting material carrying down the precipitated matters; whilst the charcoal acts to a certain extent as a deodorant. A highly clarified effluent is produced by this process, which is, however, a costly one.

The suspended matters, or sludge, of sewage being deposited at the bottom of the settling tanks, the questions arises: What is to be done with the clarified effluent? and, How is the sludge to be got rid of? No nuisance will result if the effluent is discharged into a quickly running stream or river, whose volume is at least 10 times greater than that of the effluent, and which is not used below the point of discharge as a source of supply for drinking water. The danger is lest, during drought in summer, the volume of fresh water might considerably diminish; and the effluent sewage when not sufficiently diluted, would putrefy and become turbid, forming foul deposits in the bed of the stream, and giving rise to offensive exhalations. This would be especially likely to happen if, at the same time, the temperature was high. By this method, too, all the valuable manurial ingredients of sewage run to waste. The only satisfactory mode of purifying the effluent sewage, is to carry it over land by irrigation, or through specially constructed filter beds.

Where it is not possible to obtain land for this purpose, the partial purification of the effluent from the tanks may be effected by passing it through specially constructed filters, consisting of fine sand laid upon magnetic carbide of iron. The magnetic carbide of iron exerts a powerful oxidising effect on the ammonia and organic matters dissolved in the effluent, by which these are converted into nitrates and nitrites. The slower the filtration, *i.e.*, the longer the effluent liquid is in contact with the particles of magnetic carbide of iron, the greater is the purification. The filtration must be intermittent to allow of aeration of the filter; but the magnetic carbide, when once in position, never needs renewal. When laid in beds of considerable thickness, consisting of 12 inches of sand upon 18 inches of magnetic carbide of iron, the filter is capable of purifying large volumes of effluent sewage—one acre of filter bed being sufficient to purify from one to two million gallons of clarified sewage in the 24 hours.

The sludge left at the bottom of the tank is generally swept into a well, and thence pumped out in a semiliquid condition. It contains from 90 to 95 per cent. of water. It may be got rid of by allowing it to flow, in this liquid condition, along raised carriers on to land, into which it is subsequently dug, thereby eventually becoming incorporated with the soil. This is the method pursued at Birmingham, the sewage being treated with lime, and the effluent from the tanks being purified by irrigation over the soil of the sewage farm.

If the semi-liquid sludge is allowed to dry by exposure to the air in pits, it invariably causes a nuisance, so that it is now the usual practice to press part of the moisture out of the sludge by hydraulic filter presses, by which a solid cake, containing 50 to 60 per cent. of moisture, is produced. These cakes can be stored up without causing any nuisance, and sold or given away according to the demand for such sewage manure. They may be further dried by heat in drying machines, and then ground into a granular condition, containing from 20 to 30 per cent. of moisture. In this condition the manure is far more suitable for application to land, than in the form of the coherent cakes which issue from the filter presses.

To calculate the weight of sludge cake formed from a given quantity of sludge taken from the tanks, Professor Robinson has devised the following formula.

Let W = weight of sludge from the tanks.
,, P = percentage of moisture remaining in the pressed sludge.
,, X = weight of sludge cake.

Then $X = \frac{10\ W}{100 - P}$.

The average composition of pressed sludge cake from the metropolitan sewage, Mr. Dibdin states to be:— moisture, 58 per cent.; organic matter, 16·7 per cent.; mineral matter, 25·25 per cent.; ammonia, 1 per cent.; phosphate of lime, 1·44 per cent. The value of a ton of this sludge cake, calculating ammonia as worth *7d.* per lb., is about 17*s.* This value corresponds with that obtained by calculating the suspended matters in 100 tons of sewage as being worth 2*s.* For the suspended matters from about 850 tons of sewage will be required to produce a ton of sludge cake containing 50 to 60 per cent. of moisture. This is the theoretical value: the price obtained from the sale of this sludge cake varies in different towns; in some there is no demand for it, and it is either burnt in a "destructor" furnace, used for raising low-lying grounds, or a small premium is paid to farmers for removing it.

Intermittent Downward Filtration.

When sewage is filtered through porous soil, it is purified to a greater or less extent. This purification is partly due to the soil acting as a mechanical filter, separating out and retaining the suspended matters in the sewage; but greatly more to the oxidation by the soil, of the ammonia and organic matters in the sewage, by which they are converted into nitrates and nitrites. This oxidation is in part effected by the air between the particles of soil—hence the necessity for an intermittent application of the sewage, in order that the soil may be aerated in its periods of rest; but chiefly by bacterial organisms—the nitrifying organisms of Schlœsing, Müntz, and Warrington—which exist in the upper layers, extending to 3 or 4 feet from the surface, of all soils, but chiefly in those rich loamy soils which contain much organic matter. The nitrifying organisms feed on the ammonia and organic matters of sewage, causing their oxidation. They require air and oxygen for their growth and life, which are supplied to them when the soil is being aerated during its period of rest. The soil or the sewage should also be rich in salts of lime, especially the sulphate; for the nitric and nitrous acids when formed must be able to combine with bases, or the nitrifying action ceases.

A very large volume of sewage can be purified on a small area of land, if the following conditions are satisfied:—The soil must be of a porous and rich loamy character. Sandy soils are not efficient purifiers, at any rate at first. Clay, and other retentive soils, must be well broken up and mixed with ashes. The surface of the land must be levelled, and under-drained with porous tile drains, laid at a distance of about 10 to 30 feet apart, at a depth of five or six feet from the surface. The area should be laid out in plots; and no plot should receive sewage for more than 6 hours, so that it may have 18 hours rest out of the 24. If it is intended to apply the sewage in the proportion of more than 1000 people to an acre, the sewage should be treated chemically to remove the suspended matters, and the clarified sewage only should be applied to the land.

When crude sewage is applied in large volumes to a small area of land, the pores of the soil become clogged with the slimy suspended matters, and a kind of coating is formed over the surface, which prevents the percolation of the sewage and the penetration of air into the interstices of the soil. When the sewage of less than 1000 people is to be applied per acre, the sewage may be applied in its crude state; for it is much cheaper to allow the suspended matters to reach the soil by gravitation in the liquid sewage, than to separate them by precipitation and then pump the liquid sludge onto the land. It is occasionally the practice to lay out the filter beds in ridges and furrows—the sewage being allowed to flow down the furrows, whilst vegetables are grown on the ridges. The roots of the vegetables assimilate ammonia and organic matters, and thus help to purify the sewage, whilst the leaves and stalks being above the sewage are not contaminated by floating matters. The suspended matters deposited from the crude sewage in the furrows, must be dug into the soil before they have time to form an impenetrable coating.

By intermittent downward filtration through specially prepared beds of suitable soil, the clarified sewage of even 5000 people can be applied to each acre of land. Under favourable circumstances, the effluent water issuing from the deep drains will be found almost completely free from organic matters. The nitrogen of the sewage exists in the effluent water, but in the innocuous forms of nitrates and nitrites. The chlorine will be found in the same proportion in the effluent as in the sewage. The sewage, therefore, by this process is effectually purified; but all its manurial ingredients are wasted, except in those cases where the sale of vegetables, grown on ridges, covers part of the cost of its distribution. But the area of land being so limited, the amount of crops, and the income derived from their sale, must necessarily be very small.

Irrigation.

In the words of the Royal Commission on Metropolitan Sewage Discharge, broad irrigation means "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied." Filtration means "the concentration of sewage, at short intervals, on an area of specially chosen porous ground, as *small* as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance. The intermittency of application is a *sine quâ non* even in suitably constituted soils, wherever complete success is aimed at."

It becomes necessary to inquire, what are the conditions under which the sewage of a town may be applied to land by broad irrigation, that is, how may sewage farming be rendered successful? Experience has taught that no great profit should be looked for from a sewage farm; but even if the sale of the produce helps to diminish the cost of purification, this is a result which can be attained by no other method of disposal of sewage. Unfortunately, in the past, local authorities have found great difficulty in acquiring land for cleansing sewage. Enormous prices have been asked and given for agricultural land, required for sewage farms; and these, added to parliamentary and legal costs, have in many instances saddled the rates with burdens, which cannot possibly be defrayed by the sale of sewage-grown produce.

In the first place, the land chosen should be so situated in relation to the town, that the sewage may flow to it by gravitation: pumping is costly and greatly reduces any profits that may arise. The rent to be given for the land ought not to exceed £2 10*s*. per acre (Bailey Denton). The extent of land that should be acquired varies under different circumstances; as an average, one acre to every 100 persons of the population is sufficient. The best kind of soil is a friable loam, but clayey, gravelly, or sandy soils, are all capable of purifying and utilising sewage when properly managed. The land must be levelled, and, unless very porous, underdrained to allow the sewage to percolate and prevent its stagnation on the surface. The main carriers for the distribution of the sewage on the farm, should be masonry, concrete, or stoneware channels, which can be easily flushed and cleansed.

The method most capable of general application, for applying the sewage from the main carriers to the surface of the farm, is that known as the *ridge and furrow system*. The surface is laid out in ridges—30 to 60 feet broad—running parallel to each other, and at right angles to the main carrier with a slight fall from it. Between every two ridges is a furrow formed by the slope (a fall of a few inches) of the two ridges towards each other. The flow of sewage down the main carrier being stopped by a plate or board, held by a workman opposite the centre of the ridge, the sewage overflows, and passing down a grip in the centre of the ridge, can be made to flow over the sides towards the furrow. When the central grip becomes clogged with the suspended matters of the sewage, it should be filled in, and a fresh one made in its place. The underdrains of porous earthenware should be laid at a depth of about 6 feet in the soil, and from 20 to 100 feet apart, according to the porosity of the soil.

The best crops for a sewage farm are Italian rye-grass, roots (mangold wurzel), and cabbages. Messrs. Rawlinson and Read in their report to the Local Government Board (1876) state:—"Italian rye-grass is probably in all respects the most advantageous crop to be grown under sewage; as it absorbs the largest volume of sewage; occupies the soil so as to choke down weeds; comes early into the market in spring; continues through the summer and autumn, bearing from 5 to as many as 7 cuttings in the year, and producing from 30 to 50 tons of wholesome grass upon each acre." Dr. Alfred Carpenter believes that this plant possesses the power of absorbing and assimilating unchanged the organic matters of sewage, unlike plant life in general, for which complex organic bodies must be reduced to simple constituents (ammonia, phosphates, etc.) before they can be assimilated. He thus accounts for the enormous volumes of sewage with which plots of rye-grass may be continually treated, without injury, indeed with benefit to their growth. After two or three years, the plot of rye-grass should be ploughed up, and the land sown with cabbages or roots (mangolds). These may be sewaged when growing, but they should not be sewaged when they arrive at maturity. They help to exhaust the soil of the sewage matters retained in it, which have not been absorbed by the rye-grass. Pulse, cereals, and all other vegetables, should not be sewaged when in growth, except in times of great drought. The land, when fallow, may be enriched by the application of sewage; for some of the manurial ingredients of sewage are doubtless retained in it, ready for use on a future occasion. Market gardening may be undertaken, and made very profitable on farms where the area of land is more than sufficient to deal with all the sewage; but where this is not the case, market gardening does not answer, because the area so cultivated cannot take all the sewage which it ought to utilise.

The amount of capital required to stock and work a sewage farm is very great, probably 5 times the amount required for an ordinary farm. The crops that have to be taken off the land are enormous, and a large amount of labour is required to keep the land clean and free from weeds. The crops of Italian rye-grass being so large, may—and often do—exceed the demands of the local markets. If not sold at once, the grass is wasted; for it will not keep, and will not bear long carriage. In dry summers it may be made into hay, and at other times it may be converted into Ensilage. It has been found, however, that to reap the greatest profits from a sewage farm, the produce should be converted into milk and meat. In other words a dairy farm should be established, and stock should be reared and fattened for market. The idea that sewage-grown produce is dropsical and prone to decompose, has been long exploded. The milk and meat also from animals fed on such produce, in no way differs from milk and meat produced on ordinary farms.

We may here quote some experiments of the British Association sewage committee made on Breton's farm at Romford, as to the amount of nitrogen recovered in the crops of the farm from the sewage applied. Their experiments extended over 5 years (1871-76), and they found that the average amount of nitrogen recovered in the crops of the farm was 32·88 per cent. of that applied in the sewage. About 11 per cent. of the nitrogen in the sewage escapes in the effluent water almost entirely as nitrates and nitrites, whilst a portion of the unaccounted-for nitrogen is stored up in, and enriches, the soil of the farm. These results the committee considered very satisfactory, taking into account the extreme porosity of the soil and the limited area of the land, as in the experiments of Messrs. Lawes and Gilbert only from 40 to 60 per cent. of the nitrogen applied in solid manures was recovered in the crops within the season of application.

The amount of evaporation of water from the surface of a sewage farm is enormous. The above committee found that, on an average of over a year's observations, only 47·3 per cent. of the sewage pumped on to Breton's farm was discharged through the deep drains as effluent water. This fact must be reckoned with on making analyses of effluent waters from sewage farms, which are to be compared with samples of crude sewage flowing onto the farms. Although the evaporation of water is so great, the committee found that there was no loss of ammonia from the sewage by evaporation, in its passage along the open grips and carriers on the farm.

One of the great drawbacks to the utilisation of sewage by irrigation, is the fact that the sewage must be applied to the land as it comes, by night as well as by day, on Sundays as on week days. There may be times when it may not be desirable to apply sewage to the general surface of the farm, especially during wet weather, when enormous volumes of dilute sewage arrive at the farm. This difficulty may be got over by laying out a portion of the farm as a filter bed closely drained. The extent of this filtration area should be sufficient to purify the whole of the sewage when not required on the general surface of the farm. The land may be left fallow, or laid out in ridges and furrows and cropped. When the sewage is much diluted with storm water, it may, in other cases, be carried over osier beds or meadow-land before being discharged into a stream. The flow of sewage is thereby checked, and suspended matters are to a certain extent deposited, so that the sewage is partially clarified before its entrance into the stream. It would be of great advantage if storm and subsoil waters could always be excluded from the sewers; the problem of satisfactory disposal of the sewage would be thereby greatly facilitated.

During the most severe frosts irrigation may continue uninterruptedly. A coating of ice is formed over the surface of the farm, but the sewage, which never has a temperature below 45° F., flows underneath this coating and sinks into the soil, which remains unfrozen and open. As the weather moderates, the sewage rapidly melts the ice above it. Even in America, where the frosts are most intense, no trouble has arisen from this cause on any of the sewage farms.

Are sewage farms productive of nuisance and injury to health? There can be no doubt that badly managed farms—where more sewage is applied than the land can absorb and cleanse, or where, from the sewage being applied too continuously, the surface becomes sodden, and ponded sewage stagnates on it—may be a nuisance. That they can cause injury to health or produce disease has yet to be proved. When properly conducted, sewage irrigation can produce no nuisance.

That sewage farming is no more unhealthy than ordinary farming, is shown from the returns of the 9 sewage farms which were in competition for the Royal Agricultural Society's prizes. The rate of mortality on an average of the number of years these farms had been in operation did not exceed 3 per 1000 per annum. No facts either have ever been brought forward in favour of the view that entozoic diseases are spread by the agency of sewage farms. It has been truly remarked that it is probable that alkaline sewage destroys organisms like the ova of tapeworms, whose natural habitat is the acid secretion of the human intestines. If so, they are destroyed before they arrive at the farm. On one farm too it was found that there was a remarkable absence of those molluscan and insect forms of life, which freqently play the part of intermediary bearers to entozoal larvæ, and without which the cycle of their existence cannot be continued. Even where cattle have been allowed to feed upon land to which sewage was being applied, it has not been found that they were in any way affected with parasitic diseases.

CHAPTER III.

AIR AND VENTILATION.

PURE atmospheric air has the following volumetric composition :—

Oxygen	. 20·96 *per cent.*
Nitrogen	. 79·00 ,, ,,
Carbonic acid.	·04 ,, ,,
Ozone and mineral salts. . . .	. *traces (variable).*
Organic matters, chiefly in suspension	. *traces.*
Water vapour	. *variable.*

This composition is, as regards the three gases which compose almost the entire bulk of ordinary air, remarkably uniform in every part of the world. Even in the midst of large cities where the atmosphere is being vitiated and polluted in every conceivable variety of way, the air of open spaces differs but very slightly in the proportions of its constituent gases from the air on the open plains, mountains, or seas, which is far removed from such sources of contamination. This is not to be wondered at when the immense power and universality of the forces which promote purification of the atmosphere are considered. Such are :—the winds which dilute and sweep away impurities, bringing pure air in their place ; the rain which washes the air, carrying down in its fall dissolved gases and suspended impurities ; the chemical effects of the oxygen and ozone in the air on the oxidisable matters in it ; and lastly, the power possessed by the green parts of plants in sunlight of absorbing carbonic acid, fixing the carbon and setting free the oxygen. The latter process is, however, reversed during the hours of night, CO_2 being evolved, but the balance is decidedly in favour of purification. Provided these natural forces have full play, the atmosphere everywhere maintains a constant composition and is what we call pure.

But under the artificial conditions of civilised existence, it too often happens that the utilisation of these purifying forces—the science of ventilation—is not understood, or neglected, and as a consequence the impurities, which are continually being thrown by human agencies into the atmosphere, increase faster than they can be dispersed or destroyed. Confining our attention for the present to the outer air—the air outside buildings—it has been found in large cities that when the atmosphere is stagnant, and no wind is blowing, especially during fogs, the air of open spaces may contain only 20·80 per cent. of oxygen, or even less, and the carbonic acid may exceed 0·06 per cent., with a considerable increase likewise in organic matters. Such observations have been made in London and Manchester. In the narrow closed courts or streets, surrounded by high buildings, which constitute so large a portion of the densely populated parts of these cities, the air has been found considerably more impure than the samples above given, which were taken from open spaces. The air of such places is stagnant and confined, as in a well; there is no circulation to effect a proper renewal of fresh air, and dispersion of accumulated impurities, and the sun rarely or never penetrates. Yet such is the only air supply attainable by thousands of the dwellings of the poorer classes.

Ozone, which is oxygen in an allotropic and highly active condition, is generally absent from town air, even in open squares and parks.

We thus see that although in towns much may be done by constructing wide and airy streets, by preventing the back-to-back aggregation of dwellings, and by proper restrictions as to their height, to provide for proper ventilation and purification of the atmosphere, yet its purity is liable to variations, which do not occur in the air of the open country. These variations may be only very slight in amount, but they are not unimportant. Their bearing on the health and vitality of the populations exposed to their influence is probably considerable.

Amongst suspended matters usually present in the air, to a greater or less extent, are minute particles of sand, common salt (near the sea), soot, dust of various kinds—in towns consisting largely of organic matters from horse droppings—vegetable *débris*, pollen of grasses and flowers in the early summer, the spores of various fungi and moulds, diatoms, bacteria and their spores, monads and infusoria—dead and living. The purest air, such as exists at considerable elevations on mountains and over the sea, contains but very little suspended matter, sometimes none at all. In towns, especially manufacturing towns, the air is often loaded with soot and dust of mineral origin.

The presence of bacteria in air is a subject of much interest, which has received for some years the attention of Dr. Miquel at the Montsouris Observatory near Paris. Dr. Miquel has found the air at Montsouris to contain on an average 480 bacteria per cubic metre, chiefly in the form of spores. The greatest number are present in summer, and the least in winter. Rain washes out of the air bacteria and all other suspended matters;

consequently after rain fewer organisms are present in a given volume of air. In the streets of Paris the average number of bacteria to a cubic metre of air is 3480, whilst in inhabited rooms, ten or even twenty times this number may be present. Micrococci constituted sixty per cent. of the bacteriform organisms found, the remainder being bacilli and true bacteria. Spores of fungi and moulds appear also to be present in largest numbers in summer. They are said to alternate with bacteria in different years or seasons. The cells of protococcus pluvialis and other algæ are sometimes found in air.

In towns, the amount of organic and mineral dust in the air will depend greatly on the efficiency of the scavenging and watering of the streets. The wind raises minute particles from the surface of the ground, and carries them often great distances before they are deposited. In this way infectious particles from domestic dust heaps and dried excreta, may be caught up and carried into the air. In India, where the habits of the natives greatly conduce to fæcal pollution of the surface of the soil, it is believed that dried choleraic discharges may be carried by the wind, and be the cause of an outbreak at very considerable distances.

Air is vitiated by *respiration of men and animals;* by *combustion of coal, gas, oil, etc.;* by *fermentation and putrefaction of animal and vegetable organic matters;* by *various trade and manufacturing processes.*

Vitiation by Respiration.

An adult individual at rest breathes at the rate of about seventeen respirations a minute. At each respiration about 500 c.c. (30·5 cubic inches) of air passes in and out of his lungs. The air in the lungs loses four to five per cent. of oxygen, which is absorbed by the blood in the pulmonary capillaries, and gains carbonic acid from the venous blood, to the extent of about four per cent. The nitrogen remains unchanged.

The composition of respired air is variable, but may be taken to be somewhat as follows:—Oxygen 16·96 per cent.; nitrogen 79·00; carbonic acid 4·04. In addition, the expired air is raised in temperature to nearly that of the blood, 98·4° F.; it is saturated with aqueous vapour, and contains a considerably larger proportion of putrefiable organic matters, than the air which is inspired.

The amount of carbonic acid which is given off by an adult person at rest, can be calculated from the above figures, and will be found to be 0·72 cubic foot in one hour. From actual experiment, however, it has been determined that an average adult person gives off 0·6 cubic foot of carbonic acid every hour, and this is the figure which is usually taken as the basis for all calculations on ventilation and supply of air. It probably approaches with sufficient accuracy the actual truth, when applied to a mixed community of adults of both sexes. During exercise the quantity of CO_2 given off is greater, and may reach to 1·5 cubic feet per hour during hard work.

The organic matter given off by the skin and lungs, varies with the individual and his state of health. It consists partly of vapour, and partly of suspended matters (epithelial and fatty *débris*); it is nitrogenous and oxidisable, and very rapidly putrefies. It is also absorbed by hygroscopic substances, such as wool, feathers, and moist paper; and is noticeable by smell in the air of an inhabited room, when the CO_2 exceeds 0·06 per cent. This foul organic matter is the substance which renders air vitiated by respiration so peculiarly deleterious to health.

Slight excess of carbonic acid and deficiency of oxygen are, by themselves, inoperative and without influence on health; but inasmuch as foul organic matters are present in air vitiated by respiration, just in proportion as the CO_2 is in excess, and the oxygen diminished, and as the amount of CO_2 is estimated so much more easily than the organic matters, it is usual to judge of the foulness of the air of inhabited places by the greater or less excess of CO_2 in it. The organic matters in an inhabited room are difficult to get rid of even by free ventilation; unlike the CO_2, which being nearly equally diffused throughout the apartment, is rapidly removed when there is a communication with the external air. The amount of watery vapour given off by the lungs and skin is about 550 grains per hour, enough to saturate 90 cubic feet of air at a temperature of 60° F.

The purity of the air in dwelling rooms depends upon the amount of cubic space for each individual, and the facilities afforded for entrance of fresh and exit of foul air. Where these points are properly attended to, the air, although rather more impure than the external atmosphere, will not be productive of injury to health. In those extreme cases where many people are crowded together, and the ventilation is totally inadequate, the air often becomes sufficiently impure to cause headache, lassitude, nausea, and fainting. In the pit of a theatre at 11.30 p.m., Dr. Angus Smith found the oxygen reduced to 20·74 per cent.; and in the old court of Queen's Bench in 1866, the oxygen on one occasion was as low as 20·65. In a school-room crowded with 70 girls, Pettenkofer found the carbonic acid to exist in the air to the extent of 0·723 per cent., or nearly 20 times the amount normally present in air; whilst the organic matter, measured as albuminoid ammonia (usually present in pure air to the extent of 0·08 milligrammes per cubic metre) has been found in the ward of a Hospital to reach 1·3 milligrammes per cubic metre of air.

The above figures represent in each case excessively foul atmospheres; all intermediate conditions of air, varying according to circumstances, may be found in the different kinds of inhabited rooms and dwellings. The long-continued breathing of even much less vitiated air than the above samples is perhaps one of the chief causes of rickets in children, and tends to produce a a lowered state of vitality in older people, characterised by anæmia, dyspepsia, and lassitude. People in this lowered condition of health, which is very common amongst those who spend the greater portion of every day indoors, in offices, schools, workrooms, and factories, offer much less resistance to attacks of acute disease, than do people who live out-of-door lives; and they are greatly more subject to all chronic and wasting diseases. Dr. Ogle's researches have shown that of all the industrial classes, those which are the healthiest and have the lowest death-rates, are the gardeners, farmers, agricultural labourers, and fishermen; those namely whose occupations are carried on in the open air. The death-rate from phthisis in these classes is only about half that of the male community generally, and they enjoy about the same amount of freedom from diseases of the respiratory organs. Differences in food or housing accommodation cannot account for the comparative freedom of these classes from pulmonary disease. The average agricultural labourer is probably worse housed and fed than the town clerk or mechanic, but he spends the greater part of his life in the open air instead of in a vitiated atmosphere.

The causal relation subsisting between foul air, produced by overcrowding and insufficient ventilation, and phthisis, is now generally recognised. The most convincing proofs of such a relation are to be found in the comparative immunity enjoyed by soldiers, sailors, and prisoners, at the present time from this disease. Formerly, owing to the very limited amount of cubic space allotted per head, and the disregard paid to ventilation, phthisis was considerably more prevalent amongst soldiers, R.N. sailors and marines, and prisoners in H.M. jails, than amongst the males of the same age in the classes from which they were derived. At the present time—other conditions such as food, exercise, etc., remaining much the same—the death-rate from phthisis is considerably less amongst these servants and prisoners of the State than amongst the civil population.

The theory of the contagiousness of phthisis, long ago held by those who, like Dr. Bryson, had observed the rapidity with which destructive lung diseases spread in an overcrowded community, has received the strongest confirmation from the discovery by Koch of the tubercle bacillus, an organism invariably present in tubercular deposits, but not found in any other disease. The tubercle bacillus is present in the breath and sputa, and may be thus transferred through the air from the lungs of the sick to the healthy, under conditions of too close crowding, but not apparently where matters of cubic space and ventilation are attended to, as phthisis is not found to spread in the well-ventilated wards of General or Consumption Hospitals. In fact there is reason to believe that this disease is but rarely transferred by direct contagion from sick to healthy, and that the bacilli acquire more virulent infective powers in the foul atmospheres of overcrowded rooms and damp houses, than they originally possessed on leaving the lungs of a phthisical person. As Dr. Ransome has suggested, the sporulation of the tubercle bacillus may be assisted by contact with the kind of organic matter found in such atmospheres; or whatever the explanation may be, it seems clear that phthisis is intimately connected with air vitiated by the products of respiration, or by the moisture and organic effluvia arising from damp and dirty soils, and that if such conditions are absent its capability of spreading is very limited.

The incidence of disease on the inmates of back-to-back houses, in which there can be no through ventilation and circulation of air, has been investigated for the Local Government Board by Dr. Barry and Mr. G. Smith. They report that it appears probable that the want of through ventilation has, *per se,* an unfavourable influence upon health, and gives rise to an increased mortality from pulmonary diseases, phthisis, and diarrhœa. Dr. Ransome has also brought forward evidence to show that in Manchester and Salford the streets most infected with phthisis are also the most confined and ill-ventilated, and that the larger proportion of these deaths take place in the cave-like back-to-back dwellings.

Acute diseases of the lungs, especially bronchitis and pneumonia, are very prevalent amongst those who live in heated, overcrowded rooms. The relation of pneumonia to vitiated air is especially interesting, as this disease occasionally appears to take on an epidemic form and to be infectious. In some cases of acute croupous pneumonia a micrococcus has been found in the diseased tissues, which has been supposed to be the specific cause of the disease.

An extensive outbreak of epidemic pneumonia at Middlesborough has been lately investigated by Dr. Ballard. The disease, which was distinctly infectious, had an exceptional incidence on males above the age of 15. The contagion was apparently transported directly through the air, by means of the breath, from the sick to the healthy, and also by means of infected sewer and drain emanations, and by food. Dr. Klein has discovered a bacillus in the lung juice and fresh sputa, which he regards as specific.

The zymotic diseases generally are more prevalent amongst overcrowded populations than amongst those who are better lodged; but this may be accounted for by the inability to isolate infectious cases, and consequently the ease with which contagious particles pass from the bodies of the sick to those of the healthy. Air vitiated by the ordinary products of respiration of a healthy person, may produce illness but cannot be productive of a specific disease.

In this connection we may consider the contamination of air by exhalations from the person generally. The disagreeable odour perceived in the near neighbourhood of dirty people, arises from exhalations of putrid organic matters from their bodies and clothes. The air of a London police court furnishes a striking example of such air pollution. But it is especially the exhalations from the sick that are important and require notice from the part they play in propagating disease.

In the air of ill-ventilated sick rooms and hospital wards the *débris* of dried epithelial scales and pus cells may often be found floating. These matters are especially frequent in wards, where many of the patients have purulent discharges from suppurating wounds or copious expectoration from the lungs, and are usually accompanied by an abundance of spores of fungi and bacteria, and large excess of organic matters generally in the air. In many persons the breathing of such polluted air causes an immediate effect on the throat and tonsils, passing sometimes into acute tonsillitis or hospital sore throat. Its effect in increasing the severity of, and in retarding recovery and convalescence from, acute disease, is now generally recognised. The exhalations from the bodies of patients suffering from erysipelas, ophthalmia, pyæmia, septicæmia, and hospital gangrene, are undoubtedly infectious to those who have open wounds. The contagious particles (pyogenic micro-organisms of various kinds)—contained in dried epithelial scales and pus cells—may be transferred through the air from patient to patient, and often no measure short of emptying the ward, appears to be of any avail to stop an epidemic once begun. In times not very far distant these diseases were, in the surgical wards of many hospitals, almost constantly present. Freer ventilation, improved sanitary arrangements, and the antiseptic treatment of wounds and injuries, have almost eradicated such calamities from modern hospital practice.

The transmissibility of the acute specific fevers through the air by exhalations from the bodies of the sick is universally recognised, but not so the contagiousness of phthisis, diphtheria, and typhoid fever; and it is usual even now to place such cases in wards occupied by patients suffering from mixed diseases. In the light of recently acquired knowledge this is a practice not unattended with danger, and a feeling is gaining ground that special wards should be provided for these three diseases no less than for cases of erysipelas, pyæmia, or hospital gangrene. It is possible that parasitic skin diseases may spread through the air, for sporules and mycelia of tricophyton tonsurans and achorion schönleinii have been found floating in the atmosphere of skin wards.

Vitiation by Combustion.

There are three kinds of mineral coal—anthracite or smokeless coal, bituminous coal, and lignite. Bituminous coal is used exclusively in the manufacture of illuminating gas. Anthracite is a sort of natural coke, most of its gases having been driven off during the process of formation. The bituminous kind is the only one used for domestic fire-places, although anthracite, being smokeless (no soot) when used in properly constructed stoves, would be far preferable. Bituminous coal when burnt in an open fire-place, gives off three times its weight of carbonic acid, small quantites of carbonic oxide, sulphurous acid, bisulphide of carbon and sulphuretted hydrogen, and steam. About 1 per cent. is given off as fine particles of carbon or soot and tarry matters. One pound of coal requires 240 cubic feet of air for complete combustion.

Illuminating gas is obtained by the destructive distillation of coal in retorts, without access of air. The gas is subsequently purified by condensation to remove tar and water, and by passing it over lime or sesquioxide of iron to remove sulphuretted hydrogen, carbonic acid, and compounds of sulphur and ammonia. When purified, coal gas contains on an average:—hydrogen 45 per cent., marsh gas 35 per cent., carbonic oxide 6 per cent., illuminants (ethylene, acetylene) 6 per cent., carbonic acid 3 per cent., nitrogen, sulphurous acid, etc. 5 per cent. The products of combustion of coal gas are nitrogen 67 per cent., water 16 per cent., carbonic acid 7 per cent., carbonic oxide variable—least when combustion is most perfect, sulphurous acid and ammonia. One cubic foot of gas produces when burnt 2 cubic feet of CO_2, and from 0·2 to 0·5 grains of SO_2, and is able to raise the temperature of 31,290 cubic feet of air 1° F. One cubic foot of CO_2 is produced by the combustion of about 300 grains of oil in a lamp.

All these products of combustion eventually escape into the outer air, where they are rapidly diffused and diluted, with the exception of the sooty particles which accumulate in the lower strata of the atmosphere and are only dispersed by strong winds and rain. The sulphurous acid in the air of towns causes the rain to be acid, and has a very destructive effect on vegetation, mortar, and the softer kinds of building stone. The products of combustion of coal gas usually escape into the air of the rooms where the gas is burnt, and serve to intensify the ill-effects on health of air already vitiated by respiration. Carbonic acid when present in the air even to the extent of 2 per cent., if unmixed with other impurities, appears to have no very injurious action on health; but above this quantity it produces headache and nausea, and if present to the extent of 10 per cent. or even less, it produces rapidly fatal results. Carbonic oxide on the other hand is very poisonous. One per cent. or less in the air may cause death from asphyxia, the gas uniting with the hæmoglobin of the red corpuscles and displacing the oxygen, so that the red corpuscles can no longer act as carriers of oxygen to the tissues, and failure of the chief nervous centres results.

The sulphurous acid and soot in the general air of towns like Manchester, Liverpool, and London, appear to have no very marked effect on healthy people; but they are undoubtedly injurious to asthmatics and people suffering from bronchitis. During dense fogs the mortality from lung diseases always increases. From the observed lesser incidence of malaria and diphtheria on town than on rural populations, it has been supposed that soot and SO_2 in the atmosphere might act as disinfectants, preventing the propagation and spread of these diseases; but it is probable that the greater dryness of the soil in sewered towns is a more important factor in securing this comparative immunity.

In a paper read before the Society of Medical Officers of Health (April 15th, 1887), Professor Corfield has called attention to cases of relaxed and ulcerated sore-throat caused by slight escapes of coal gas into houses from defective pipes or burners. Coal gas also occasionally finds its way into houses from leaky or fractured mains in the street. The gas passes through the soil and escapes under the basement floor, or even finds its way up the walls behind panelling. When the escape is large in amount, the effects produced on persons inhaling the gas are of an asphyxial type due to the contained carbonic oxide; but when the escape is small but long continued, the sulphur compounds, and especially the bisulphide of carbon, appear to be the injurious factors affecting the throat. These effects of escape of gas would probably be most intense where the gas is insufficiently purified after manufacture.

Vitiation of Air from Decomposition of Organic Matters.

Animal and vegetable organic matters in cesspools and in badly constructed sewers and drains, ferment and putrefy, disengaging gases, some of which are fœtid and highly complex bodies, probably carbo-ammoniacal and allied in chemical constitution to the compound ammonias (methylamine and ethylamine), whilst others are the simple gases carbonic acid, sulphuretted hydrogen, ammonium sulphide, carbon bisulphide, carburetted hydrogen, nitrogen, etc. Recent research tends to show that the organic vapours arising from decomposition of animal substances may contain traces of the animal alkaloidal substances—ptomaïnes and leucomaïnes—which are contained in the fæcal and urinary excretions of the animal body, and which exert a directly poisonous action on the system. The carbo-ammoniacal vapours have a strongly offensive odour, and are found in the air of cesspools and sewers where fermentative processes are in action. The bursting of bubbles of gas in the putrefying fluid, and the ascensional force of evaporation also carry up into the air suspended particles of organic matter and a fine liquid spray, which mix with the organic vapours and other gases given off. These suspended particles are dead organic *débris* and living organised germs (bacteria, moulds, and fungi, and their spores).

The micro-organisms—the bacteria and fungi—are the constituents of sewer air to which attention has been lately most directed. The earlier researches on the subject were for want of means necessarily very inadequate. But since the introduction by Koch of the employment of solid nutrient media for the cultivation of micro-organisms, the study of microbes in air has made rapid strides, notable improvements having been effected by Hesse, Miquel, and a host of continental observers, and by Percy Frankland, Carnelly, Haldane, Robertson, and others in this country. The net result of these later observations is to show that, contrary to what might have been expected, sewer air is, under ordinary conditions, remarkably free from the microbes which are capable of cultivation on solid nutrient media at ordinary temperatures, and of which alone have we at present any definite knowledge. By ordinary conditions are meant sewers of modern construction, well laid with good gradients, and comparatively free from deposits, the result of stagnation.

Several observers have shown that sewer air may even possess a relatively less number of microbes, capable of forming colonies on cultivation, than the atmospheric air outside. The explanation appears to be that the internal walls of sewers are more or less wet or moist, and it is assumed, probably with reason, that the microbes in the sewer air adhere to the damp surfaces, and are thus prevented from floating in the air. This reasoning is strengthened by what is already known of the presence of microbes in atmospheric air generally; for in dry dusty weather they are found in far larger numbers than in damp weather or after rainfall. In well-made sewers the sewage is borne away from the houses in a fresh and undecomposed condition; but in old and defective sewers, and even in moderately good ones when the temperature of the air is high, and the amount of diluting water is small—as during hot and dry summers—putrefactive bacteria undergo enormous multiplication, fermentative changes are set up in the sewage, and gases are formed which bubble up and break upon the surface of the liquid.

It was demonstrated as long ago as 1871 by Professor Frankland, that liquids flowing smoothly in channels give off no solid particles to the air, and that even considerable agitation resulting in frothing may not cause any perceptible increase of the solid particles in the superincumbent air, but that the bursting of bubbles of gas in a liquid had a marked effect in disseminating solid particles. These experiments have been repeated and extended by subsequent observers, and there can be little doubt but that given stagnation and putrefaction of sewage, sewer air will be found to be loaded with micro-organisms of different kinds. The experiments of Haldane and Carnelly, which have been recently made, also show that splashing in a sewer, which may be caused by branch drains entering near the crown of the sewer, is productive of the dissemination of micro-organisms in the air.

From the above results it might be inferred that sewer or drain air is only likely to be injurious when the contained sewage is undergoing putrefaction, and that as a foul odour is the invariable accompaniment of putridity, offensiveness is a sufficient criterion of possible danger to health. As to the first point, practical experience to a certain extent supports such theoretical reasoning; towns which have adopted improved sewerage have lowered their death-rates, especially the enteric fever and diarrhœa mortality. But it must be remembered that the *quantity* of bacterial organisms—of which the vast proportion are harmless—is no index of the *quality*. Under certain unknown conditions, sewer air is dangerous to breathe whether derived from fresh or putrid sewage, and the assumption that sewer air is harmless because it may contain but few *demonstrable* organisms is utterly unwarranted. All we can assume is that there is *a priori* a greater probability of noxious germs being present, when the total number is large in amount than when it is small. As regards the second point, offensiveness does not always indicate putridity; fresh sewage may contain volatile aromatic bodies of most offensive odour. In London, sewer air is often characterised by a faint, sickly, but overpowering odour; the odour of decomposition is not perceptible, yet there is plenty of evidence to prove that the inhalation of such air has been the cause of injury to health or actual disease.

The effects on health produced by the inhalation of the products of decomposition of the animal and vegetable organic matters contained in drains, cesspools, and sewers, are various. Occasionally, as when choked drains or foul cesspools and privies have been opened and cleaned out, acute mephitic poisoning has resulted; the symptoms being sudden and violent vomiting, purging, and headache, followed by acute prostration, sometimes fatal. Amongst the Paris scavengers who empty cesspools, partial asphyxia appears not to be uncommon, and is probably due to the excessive amount of sulphuretted hydrogen, disengaged when the contents of the cesspools are stirred up, together with a very low proportionate volume of oxygen.

As a rule, the injurious effects of sewer air may be attributed to the organic matters with which it is so often laden. This is especially the case when people are exposed to escapes of sewer air into houses for a long period. The dose of the poison may not be sufficiently great at any one time to cause the acute symptoms above described; but the long-continued inhalation of diluted sewer air tends to produce a general loss of health, especially in children, shown in various ways, as by anæmia, loss of appetite, prostration, diarrhœa, fever, headache, vomiting, and sore throat; one or more of these symptoms being usually more prominent than the rest; or it may be that only a condition of depressed vitality is produced, which offers but slight resistance to attacks of acute disease.

Occasionally a severe form of tonsillitis attacks the occupants of a badly drained house. This form of tonsillitis, which is now generally recognised as "sewer air throat," is marked by great inflammatory swelling of the tonsils, very foul tongue, and gastric derangement, accompanied by severe headache and intense depression. The temperature of the body is often not much raised, certainly not to a height proportionate to the severe symptoms; and this low temperature, together with the intense prostration, are characteristic of most illnesses resulting from the entrance of sewer-polluted air or water into the system. To what particular constituents of sewer air we are to attribute these and allied illnesses, it is difficult to determine. The attacks of tonsillitis, diarrhœa, etc., are not specific complaints. They are not protective from future attacks; and although there is some evidence of the "sewer-air" throat being contagious and directly transmissible from person to person, it is equally likely that examples of apparently direct contagion are really due to exposure to a common cause.

Modern views tend to regard as efficient causes the organised living germs, which may be present in sewer air, rather than any gases or vapours, however complex in their chemical constitution. But whether these micro-organisms are the ordinary bacteria and fungi of putrefaction and fermentation, which on entrance into the body pervert the healthy action of the tissues, causing diseased processes; or whether they can exist outside the body as true pathogenic organisms, must be left to future research to elucidate.

Inquiries have from time to time been made into the health of sewer men, who are constantly engaged in flushing and removing deposits from sewers. The results of such investigations lead rather to the belief that the constant breathing of sewer air is not injurious to health and life. But it must be remembered that these are picked men in the prime of life, who, now at any rate, generally work in well-ventilated sewers, where the air is not abnormally foul, and that these inquiries have not been very exhaustive. It appears, too, that they suffer somewhat from ophthalmia, and that the occupation tends greatly to aggravate venereal disease. The work is certainly unsuited to some constitutions, as many men are obliged to give it up after a short trial.

Diarrhœa and dysentery are sometimes caused by breathing air contaminated with excretal emanations. This indeed seems to be one of the chief causes of the summer diarrhœa, which is so common in a hot and dry season in the badly drained districts of large towns. In the case of Leicester, which for many years has recorded a summer diarrhœa mortality exceeding that of any other large town, Dr. Tomkins, Medical Officer of Health of the Borough, has shown that soon after the temperature of the earth, at a depth of one foot, has reached 59° F. to 62° F., the causes producing the disease begin to operate. In the low-lying districts of the town the sewers are foul, the solids of the sewage are deposited in the sewers, whilst the liquids percolate through the walls into the surrounding soil. This polluted condition of the soil Dr. Tomkins regards as eminently favourable to the development of bacterial forms of life, when the temperature reaches a certain point (59° to 62°); for the disease appears annually when the earth temperature reaches this point, and declines as the temperature declines. He also finds that in those districts of the Borough where diarrhœa is most prevalent, the air is most contaminated with microbes or their germs or spores; and that these same microbes, when artificially cultivated, possess the power of inducing diarrhœa in the human subject. The low-lying position of the town which was, until lately, liable to periodical flooding by the river, helps to intensify the results (see Chapter IX., Diarrhœa).

There is now being accumulated a very considerable body of evidence to show that puerperal fever may be produced by sewer or drain emanations finding their way into the chamber of a lying-in woman. Erysipelas, pyæmia, septicæmia, and hospital gangrene, if not caused by such emanations, are certainly favoured in their spread where conditions of excretally polluted air exist. In a west-end hospital in London these diseases were a constant scourge, although every care in nursing and attendance was taken, until the ground on which the hospital was built had been opened up and several disused cesspools emptied and filled in, the existence of which was previously unknown.

There can be but little doubt that enteric fever is also caused by inhaling specifically infected sewer air, although the more frequent mode of origin is the drinking of specifically polluted water. Outbreaks of the fever have been recorded in many instances where the water was not at fault, where the passage of infected sewer or cesspool air into houses was a proved possibility, and was the only means by which healthy people could have been brought in contact with contagion. The evidence as to the spread of cholera by such means is of a similar nature.

When excretal or other offensive emanations are given off into the open air, they are much less liable to cause disease or injury to health than when they find way into confined spaces, such as narrow courts or the interior of houses. In the open air they are rapidly diluted and oxidised, and rendered practically harmless. In this way we can account for the excellent health enjoyed by the workmen on sewage farms, and by those who live in the neighbourhood, as well as by the men engaged at sewage works. In China the practice of covering the soil for agricultural purposes with fresh human fæces has been pursued from time immemorial, and yet there is no evidence to prove that filth diseases are at all more prevalent amongst the Chinese than amongst other nations. Grossly polluted rivers, which give rise during hot weather to most offensive emanations, have not yet been proved to cause injury to health by such means alone. The same may be said of effluvia from manure manufactories, soap works, tallow works, and other offensive trades, and also of the effluvia from putrefying animal bodies, given off into the open air. The air of crowded graveyards and vaults contains excess of CO_2 and organic vapours (carbo-ammoniacal); if such polluted air rises from the soil and escapes into houses built on disused burial sites, it may cause serious sickness amongst the occupants; but when the vapours escape into the open air, even in the midst of towns, no marked injurious effects appear to arise.

The air over marshes is impure from the large amount of decaying vegetation in the water and soil. Carbonic acid, sulphuretted hydrogen, and carburetted hydrogen (marsh gas), are generally present in some excess, together with decaying organic matters, both in the form of vapour, and of suspended matters which are carried into the air by the ascensional force of evaporation. In some marshes the air is very rich in H_2S, and the symptoms of anæmia and prostration characteristic of malarial poisoning have been thought to be partly due to this gas. The suspended matters in marsh air consist of vegetable *débris*, diatoms, algæ, fungi, bacteria and other micro-organisms. These suspended particles or some one of them (the bacillus malariæ of Klebs and Tommasi-Crudeli) are the active agents in the propagation of malarial poisoning. They may be wafted by the wind considerable distances, and retain their various properties unimpaired by considerable dilution and oxidation, unlike the specific poisons evolved into the air from infected excretal refuse.

Vitiation of Air in Industrial Occupations.

Although in some trade-processes injurious *gases* are evolved and escape into the air that must be respired by the workmen engaged in the trade, and which will be considered subsequently, yet the vast majority of industrial occupations are injurious or otherwise according to the amount and nature of the *dust* which is produced. As subsidiary factors of high importance must be considered the conditions under which the dust-producing work is carried on, whether in the open air, in well ventilated workshops or factories, or in overcrowded close rooms at a high temperature and with the air saturated with moisture. The long-continued inhalation of dust tends to produce disease of the lungs, especially bronchitis and emphysema, interstitial pneumonia and fibroid phthisis. The source of the dust, whether vegetable or mineral, is not so important as the character of the particles which compose it. The most injurious kinds are those whose particles are hard, sharp, and angular, which become impacted in the walls of the bronchioles or air-cells of the lungs, are not easily expectorated, and set up irritation and chronic inflammation of the tissues around. The soft or rounded particles are not capable of doing nearly so much mischief.

Comparative Mortality of Males, 25 *to* 65 *years of age, in certain Dust-inhaling occupations, from Phthisis and Diseases of the Respiratory Organs.**

	Phthisis.	Diseases of the Respiratory Organs.	Phthisis and Diseases of the Respiratory Organs
Coal Miner	126	202	328
Carpenter, Joiner . . .	204	133	337
Baker, Confectioner . .	212	186	398
Plumber, Painter, Glazier .	246	185	431
Mason, Builder, Bricklayer .	252	201	453
Wool Manufacturer . .	257	205	462
Cotton Manufacturer . .	272	271	543
Quarryman (stone, slate) .	308	274	582
Cutler	371	389	760
File Maker	433	350	783
Earthenware Manufacturer .	473	645	1,118
Cornish Miner . . .	690	458	1,148
All Males (England and Wales)	220	182	340
Fisherman	108	90	198

* Dr. Ogle's Report, Supplement to the 45th Annual Report of the Registrar General.

The table (see p. 207) gives the comparative mortality figures for males in different dust-inhaling occupations; the comparative mortality figure from all causes amongst males in England and Wales being taken at 1000, 220 of which are due to tubercular phthisis, and 182 to other diseases of the respiratory organs. It is important to note that the column under phthisis represents the tubercular form of this disease, but undoubtedly includes many cases of fibroid phthisis as well.

That *coal miners* should stand at the head of the list, as regards freedom from lung diseases, is somewhat surprising, considering that the air in the underground passages in which they work, even in the best ventilated mines, is vitiated by respiration, combustion of lights, and gunpowder blasting, which throws into the air much CO_2, CO, H_2, H_2S, etc. In addition, CO_2 and CH_4 are often evolved in considerable volumes from the strata cut through by the shafts and borings, and the air in the workings is always thick with coal-dust. Dr. Ogle explains the comparative innocuity of coal-dust in causing lung disease, by the microscopical character of its particles which are comparatively free from sharp points and corners. He is also inclined to attribute to coal-dust a special property of hindering the development and arresting the progress of tuberculosis—a disease, it is to be remembered, which might be expected to be very fatal to coal miners, from the fact of their working in a heated vitiated atmosphere, and being liable to sudden alternations of temperature in going to and leaving off work.

This comparative immunity from tubercle is not displayed by the *Cornish* or *tin miners,* who come at the bottom of the list. Their mortality from lung diseases constitutes nearly two-thirds of their total mortality, and is nearly three times as great as that of Cornish males generally. They work under conditions of heated and vitiated air like the coal miners, but they inhale a sharp, angular, and most irritant stone-dust, instead of the comparatively benign coal-dust. The other occupations in which the workers are exposed to the inhalation of stone-dust are, *masons*, *builders*, and *bricklayers*, who carry on their work chiefly in the open air, and have a lung disease figure of 453; *stone* and *slate quarrymen* who also work mainly in the open air (582); and the *earthenware*, *china*, and *pottery manufacturers* who suffer enormously from bronchitis and emphysema (potter's asthma), and phthisis. These latter carry on their trade in close and heated factories, and, besides the fine irritating dust, are exposed to great vicissitudes of temperature. Their lung disease mortality is nearly the same as that of the tin miners.

Cutlers and *file makers*, *needle*, *pin*, and *tool makers*, are exposed to metallic dust and stone-dust given off from the grindstones, and suffer largely from phthisis, bronchitis, and pneumonia. File makers are in addition liable to lead poisoning, from their using a cushion of lead on which to strike their file. The operatives in *cotton factories* work in a heated atmosphere laden with filamentous particles of cotton and mineral substances used for sizing. In *woollen factories* the heat is not so great, and there is less dust owing to the wool being treated with oil; but woolsorters are liable to contract anthrax from infected fleeces. In *silk mills*, dust and high temperature are injurious to the material, and are consequently avoided.

Millers and *bakers* are liable to inhale flour dust, but as this substance is probably arrested in the mouth and nose, and does not reach the lungs, it can hardly be regarded as productive of lung disease. *Carpenters, joiners*, and *cabinet makers* are exposed to wood dust. The dust from the harder kinds of wood is probably more injurious than that from the softer kinds.

Printers and *earthenware manufacturers, plumbers, painters, glaziers*, and *file makers* are all subject to lead poisoning; but plumbers, painters, and file makers in the highest degree. Plumbers inhale volatilised oxide of lead, and painters the dust of white lead; but lead is also taken into the system when meals are eaten with dirty hands. Gout, renal disease, and diseases of the heart and brain are also common in these trades, and are the sequelæ to a large extent of the lead poisoning.

Other trades which give rise to dust or injurious fumes are, the manufacture of arsenical wall papers and artificial flowers, causing a dust which irritates the skin of the exposed parts and induces a rash, and on inhalation may produce symptoms of arsenical poisoning; chemical works producing sulphuretted hydrogen gas in large quantities; cotton and worsted bleaching works where sulphurous acid is given off, causing occasionally bronchitis and anæmia; alkali works giving off hydrochloric acid vapours; vulcanised india-rubber works producing bisulphide of carbon; and cement works and brickfields where CO_2, CO, H_2S, SO_2 gases are evolved.

In brass foundries the workers inhale a metallic dust, which is productive of a disease until lately known as "brass-founder's ague." But Dr. R. M. Simon* has shown that brass-worker's ague is not ague at all, and is not in any way allied to malarial poisoning. The symptoms which caused Dr. Greenhow to designate the disease brass-worker's ague, are shown to be due to the ingestion of a quantity of an irritant metal dust (copper

* *British Medical Journal*, April 28th, 1888.

and zinc) sufficiently large to cause vomiting with its attendant depression. The illness only occurs in those who are new to the work, or who resume work after an absence of a month or even a fortnight, and there are no hot or sweating stages as in true ague. The men who suffer in this way drink freely of milk and promote vomiting, the best treatment that could be devised for copper or zinc poisoning. Chronic copper poisoning is common amongst brass-workers, and bronchitis from inhalation of irritant dust. In the manufacture of bichromate of potash a dust is inhaled which causes nasal ulceration. Match makers, before the introduction of red or amorphous phosphorus, used to suffer from necrosis of the jaw, the result of exposure to phosphorus fumes; and silverers and gilders, who worked with amalgams of gold and silver with mercury, were formerly the subjects of mercurial poisoning, until electro-plating by electrolysis replaced the old methods.

Two other occupations may be mentioned, in which the workers are exposed to carbonic acid gas inhalation. These are well-sinkers, who are occasionally asphyxiated by the large amount of this gas which is evolved from the soil, and collects in deep shafts; and soda-water manufacturers. In this latter occupation, however, the CO_2 is never present in the air in sufficient quantity to cause injury to health or life.

The offensive trades mentioned in the Public Health Act of 1875 are those of blood-boiler, bone-boiler, fell-monger, soap-boiler, tallow-melter, tripe-boiler. The model bye-laws of the Local Government Board include in addition those of blood-dryer, leather-dresser, tanner, fat-melter or fat-extractor, glue-maker, size-maker, and gut-scraper, as being trades for which regulation by sanitary authorities is desirable.

These regulations have for their object (1) the keeping of offensive stores in proper receptacles, so as to prevent the emission of noxious effluvia; (2) the daily removal of offensive waste materials, or their storage, when they must remain on the premises, in properly covered vessels or receptacles, to prevent nuisance; (3) the regular cleansing of the premises, and the enforcement of adequate ventilation, water supply, and drainage; (4) the discharge of all vapours and gases, produced in the course of manufacture, at such a height into the air as to render the noxious effluvia not injurious to the neighbourhood; or in certain cases the gases must be passed through the furnace and destroyed before discharge. In other cases the gases must first be passed through a condensing apparatus, to condense steam or other vapours by a low temperature; or by passage of the gases through water or over certain chemicals, solution or absorption of the noxious vapours may be attained.*

The Local Government Board has also issued model bye-laws for the regulation of slaughter-houses, and for the prevention of the keeping of animals on any premises so as to be injurious to health.

The Alkali Works, etc., Regulation Act of 1881, provides that 95 per cent. of the hydrochloric acid gases and vapours produced in alkali works must be condensed; and in each cubic foot of air, gas, or smoke escaping into the atmosphere there may be only $\frac{1}{5}$ grain of HCl. Each cubic foot of air, gas, or smoke, issuing from sulphuric acid works must not contain more than 4 grains of sulphuric acid (SO_3). The keeping apart of acid drainage and alkali waste is strictly enforced; and all waste substances must be got rid of without nuisance. Other works included in this Act are salt

* See Dr. Ballard's Report on Effluvium Nuisances.

works, cement works, chemical manure works, nitric acid works, sulphate and chloride of ammonia works, chlorine works, bleaching works, and gas liquor works.

Nuisance may also result in the neighbourhood of gas works by the accumulation of deposits of lime, removed from the chambers where the ammonia and sulphur compounds are absorbed from the coal-gas.

Household Dust.

Besides vitiation by products of respiration and combustion, one great cause of impurity of air in houses is the presence of floating particles of dust. This dust is the *débris* arising from the wear and tear of articles in domestic use, mingled with the soot and ashes from fireplaces, lamps, and gas burners. As soon as the air is still, it tends to settle upon walls, floors, and articles of furniture, to be again caught up and wafted into the air, when this is in brisk movement. Under the microscope this dust resolves itself into soot, mineral particles (sand, crystals of sodium chloride), cotton fibres, spores of fungi or bacteria, starch grains, pulverized straw, epithelial and epidermic *débris* from the skin. It is thus seen to consist largely of organic refuse, often more or less putrescent, and its presence in the air assists in the production of the low state of health so common to the occupants of dirty, overcrowded houses.

In all houses dust must be produced by the wear and tear of domestic life; but in towns this strictly domestic dust is much augmented by that which finds its way in through doors and windows from the outer atmosphere. We cannot hope then to materially limit its production; but much may be done to get rid of it, and to prevent its undue accumulation by thorough and regular house-cleaning.

House-cleaning can only be efficient where the structural conditions of walls, floors, and ceilings, permit of easy access for the broom and duster into every part of the room, and where furniture and fittings are so arranged as to prevent dust being deposited in inaccessible places.

As generally arranged, nearly every part of a room is a dust-trap. Cornices and projections on ceilings and above doors; rough or flock wall-papers; floors with crevices between the boards into which dust drops, to gradually accumulate between the floor and the ceiling below; carpets accurately fitting every corner of the room; cumbersome articles of furniture as wardrobes, side-boards, and book-cases, which collect dust above, and are too heavy to be moved to allow dust to be swept out below; heavy curtains with canopies, draperies, etc.; all these tend to the collection or absorption of dust, which, being unseen, is forgotten and not removed.

It is especially in bed-rooms, which are occupied for so many hours without any thorough renewal of the air, that these dust absorbers and accumulators tend to do so much harm, by contaminating an atmosphere already sufficiently vitiated. The following rules therefore, although to be recommended in every room of a house, are more especially applicable to bed-rooms.

The floors, if old and warped, should be accurately fitted with thin oak parqueterie, kept well polished with oil and beeswax; or the spaces between the boards may be filled in with strips of wood, so as to leave no chinks, and the whole either stained and varnished, or coated with three or four good coats of paint, and varnished. This flooring can be kept clean with a damp duster. Carpets should be abolished in favour of mats or Indian matting for bed-rooms, which is very non-absorbent and easily cleaned. The mats can be frequently shaken and beaten in the open air, whereas fixed carpets are usually beaten once a year, and in the interval accumulate (especially the thick pile carpets) every kind of refuse and abomination. The use of linoleum and oil-cloth should be avoided, as it hinders the ventilation of the boards, and tends to cause dry-rot.

Heavy curtains, canopies, and draperies should be replaced by light muslin fabrics—more especially in bed-rooms—which can be washed and cleaned at frequent intervals. Bed-room furniture should be light and easily moved. It would be a great improvement, if, when houses were built, the bed-room walls were planned with recesses, which could be converted into cupboards, shelves, and drawers; and thus the actual furniture of a bed-room could be reduced to the bed, wash-stand, dressing-table, and chairs, and there would be no surface on which dust could lie concealed.

Cornices and projections from walls and ceilings should be avoided, as likely to collect dust.

The wall coverings should be smooth and glossy. Rough wall-papers, especially flock-paper, can hold enormous quantities of dust. For bed-rooms and nurseries, distemper colouring is perhaps better than wall-papers, as the surface can be renewed at trifling cost, and at frequent intervals. In distempering, common whiting is used as a basis for the colouring, and not white lead or zinc white, as is almost invariably the case in painting. Newly painted surfaces give off traces of lead, volatilised or in powder, to the air in drying; and symptoms of lead-poisoning are not uncommon in the occupants of a freshly painted room. Painting, then, is not to be recommended for wall-surfaces, unless the paints are warranted free from lead. Sometimes the paints themselves contain no lead, but the "dryers," with which they are mixed before use, are found to be full of lead.

Varnished wall-papers are coming more largely into use. They have a smooth non-absorbent surface, and are easily cleaned with a damp cloth. In papering a room it is important to see that the old paper is all peeled off, and the plaster underneath well washed, before the new paper is applied. The size and paste used should be perfectly fresh.

A paper should never be put on a wall unless it is guaranteed free from arsenic; and it is even advisable to test a piece with Marsh's or Reinsch's apparatus to make perfectly certain. The general supposition is that wall-papers are not likely to contain arsenic, unless they are coloured some shade of green. But arsenic has been found in various coloured papers—reds, mauves, browns, and greys. The arsenite of copper (Scheele's green) and the aceto-arsenite of copper are principally used in the manufacture of green papers. The amount of arsenic present varies in different cases from a grain, or less, per square foot, up to 50 or 60 grains.

The injurious effects of arsenical wall-papers appear to be due to the dissemination of the vapour of arseniuretted hydrogen, or of solid particles of arsenic, as dust, into the air of the apartment. In flock papers coloured with arsenic, it is probably diffused as dust; whilst in the smoother papers arseniuretted hydrogen is formed by the decomposition of the size and paste on a damp wall acting chemically on the arsenical salt.

The long-continued inhalation into the lungs or swallowing of the arsenical dust and vapours derived from wall-papers, tends to produce a chronic form of poisoning, characterised by one or more of the following symptoms arranged more or less in the order of their appearance; viz., conjunctivitis and lachrymation, cough, nausea, sickness and diarrhœa, colic pains, cramps, dryness of the mouth and throat with much thirst, headache, and debility becoming gradually very marked, with actual paralysis of the extremities, terminating in convulsions and death.

As a rule the symptoms do not go beyond conjunctivitis, cough, nausea, and diarrhœa, with much debility. But these cases of illness often last for a long period, until indeed the source of the poisoning is discovered. The artificial fruit and flower makers suffer from arsenic poisoning in its worst forms.

Ventilation.

Ventilation is a term which has a somewhat extensive meaning. Generally it may be said to mean the removal and dispersion of foreign gases or suspended matters, which have accumulated in the atmosphere as the result of the vitiating processes already described. We speak of the ventilation of streets and buildings, the ventilation of inhabited rooms, factories, and mines, and the ventilation of drains and sewers. In each case the same object is aimed at, but the means by which it can be obtained are different. The ventilation of streets and buildings is concerned with the width of the street, and the height of adjoining or opposite buildings—in fact with the amount of free air space around the buildings, and the facilities afforded for the entrance of light and air. This may be called external ventilation. To ventilate dwelling houses, factories, or mines, fresh air from outside must be introduced within these more or less closed places by natural or artificial means, and adequate exit must be provided for used or vitiated air. It is the same for drains and sewers, with this addition, that the escaping air must be allowed exit at points where it is least likely to be productive of nuisance.

The constant composition of the atmosphere everywhere, and the means by which such constancy is maintained have been already alluded to (see p. 184). In addition to the natural forces of rain, wind, sun, and vegetation, which promote the purification of the atmosphere on the large scale, *natural ventilation* as applied to circumscribed localities may be said to depend upon (1) *diffusion of gases;* (2) *the action of the winds;* (3) *the difference in weight of masses of air of unequal temperature.*

1. Gases diffuse inversely as the square roots of their densities; and this diffusion can take place through porous substances such as dry bricks. The process is necessarily a slow one, and inadequate to produce complete renovation of vitiated air.

2. Winds are very powerful ventilating agents. They act chiefly by *perflation, i.e.*, by setting masses of air in motion, driving them onward by an irresistible *vis a tergo.* They also have an *aspirating* effect on air which is shielded from the direct or perflating action. For when wind passes horizontally over chimneys, or tubes placed at right angles to its course, it causes a diminution of pressure within them, thus creating a current of air up the chimney at right angles to itself. The air in these tubes being partially aspirated or sucked out by the action of the wind, to restore the temporary vacuum so made, air

from below rushes up to take its place, a continual current in a perpendicular direction being thus set up.

3. When air is heated it expands. The expansion is equal to $\frac{1}{491}$ of its volume for every degree Fahrenheit, or $\frac{1}{273}$ for every degree Centigrade. A volume of hot air is consequently lighter, bulk for bulk, than the same volume of cold air. The warm air rises, and equilibrium is restored by the cold air rushing in to occupy its place. The winds themselves are caused in this manner by the unequal heating of the air over different parts of the earth's surface.

External Ventilation (*Streets, Buildings, etc.*).

The health of a town largely depends on the width of its streets, the general height of the buildings, and the amount of yard space at the rear of each which separates it from its opposite neighbour. Contrast the health and vitality of the occupants of houses in wide open streets, with those who live in narrow courts closed at one or both ends—the courts themselves being often surrounded by higher buildings, or built back-to-back, or with the smallest possible intervening space. In such places the air is almost always necessarily stagnant, as the passage of the wind is obstructed by the surrounding buildings. The sun's light for many months in the year cannot penetrate; with the result that the ground is never thoroughly dried, and the air in contact with it remains continually damp. Impure gases and exhalations, evolved from the inhabited dwellings, are not at once swept away by the wind, and consequently accumulate in the air of the court and its surroundings. Suspended organic matters tend to subside in the still air, which being thus both damp and impure, produces that state of low vitality and predisposition to disease which characterises the inhabitants of such places.

Zymotic diseases—especially typhus—when once introduced, spread rapidly through the vitiated air; the enfeebled constitutions of the inhabitants presenting but slight resistance to their onset. Absence of sunlight appears to have a specially injurious effect on child life, which like plants becomes blanched and weakly when reared in semi-darkness. When it is added that in many of these courts and alleys the houses have no through ventilation, the windows being only in the front of the house, it is not to be wondered at that the general death-rate is sometimes double or even treble that of the healthy parts of the town, and that the mortality amongst infants and young children is something appalling.

To show what is the minimum amount of external air space which should be allotted to every building in a town, we may quote from the model bye-laws of the Local Government Board, having reference to new streets and buildings.

The width of every new street intended for use as a carriage road must not be less than 36 feet; if not to be used as a carriage road it must be at least 24 feet wide, and open at one end. Twenty-four feet is the least width allowed before the frontage of any new building; and the aggregate amount of yard space at the back of such a building, and belonging to it, must not be less than 150 square feet, and whilst extending the entire width of the building it must not in any case be less than ten feet wide, and must be wider when the height of the building exceeds fifteen feet.

It is important to note that the model bye-laws insist on the yard space at the back of a house being increased with the height of the house up to 35 feet, but not so the frontage area. The higher the buildings, of course the greater the obstruction to the passage of air and light; and the amount of space compulsorily left unoccupied, both in front and back, should have been correspondingly increased. The erection in London and some large provincial towns of huge blocks of industrial dwellings, whilst affording vastly superior accommodation to the working classes over the old insanitary tenements, has not always secured efficient external ventilation for certain of the tenements. Lofty blocks are too often built in such a way as to enclose a narrow and well-like court, in which the atmosphere is always sunless and stagnant, and from which the rooms facing on to it derive all their light and air. Cottage buildings with sufficient space in front and rear, are far preferable to lofty blocks placed in rows; but as they do not house the same number of people for the space occupied, in crowded districts, where the land is of such enormous value, the rents must necessarily be higher.

Ventilation of Inhabited Rooms.

We have already seen that an adult individual when at rest expires about 0·6 cubic foot of CO_2 in one hour, and that it is convenient to estimate the CO_2, when determining the vitiation of air by respiration; for although this gas is not *per se* the harmful product of the respiratory process—being in fact comparatively innocuous when present in but slight excess—yet it is an index of the amount of vitiation of the air by the fœtid and injurious organic matters of the breath—

increasing *pari passu* with them during the process of respiratory vitiation.

In providing for the ventilation of inhabited rooms by the replacement of vitiated air by fresh air, it has been found necessary to adopt a certain standard of impurity above which no increase should be allowed; because it is impossible in a cold climate to provide the enormous volumes of fresh air (about one million cubic feet for each individual per hour) which would be necessary to keep the air of the room as pure as the outside air. It is only out-of-doors then, that we can be constantly breathing air whose purity, as indicated by its amount of CO_2 (0·04 per cent.), is equal to that of the atmosphere generally.

It has been found by Professor De Chaumont, by chemical examination of a large number of samples of the air of inhabited rooms that—the amount of CO_2 in the outer air being 0·04 per cent., or 0·4 per 1000—no close or disagreeable smell is perceived in the air of a room until the CO_2 reaches 0·6 per 1000, or exceeds by 0·2 per 1000 that present in the outer air; the close smell being always due to the foul organic matter in the impure air, which increases *pari passu* with, and is therefore estimated by the amount of CO_2 present. When the CO_2 in an inhabited room reaches 1·3 per 1000, the limit of differentiation by the sense of smell, when a person first enters such a room from the outer air, is reached. Any greater impurity than this cannot be distinguished by the unaided senses. It has been assumed by De Chaumont, and experience has confirmed his assumption, that air vitiated to the extent of 0·2 per 1000—air which is still fresh and does not differ sensibly to smell from the outer atmosphere—can be breathed with impunity, but that no greater vitiation ought to be allowed. The object of ventilation may be said to be the supply of sufficient pure air to a room to prevent the CO_2 rising above 0·6 per 1000. The permissible limit of respiratory impurity is therefore 0·2 per 1000 (0·2 parts of CO_2 per 1000, or 0·2 cubic foot of CO_2 per 1000 cubic feet of air; which is the same thing as 0·0002 cubic foot of CO_2 per 1 cubic foot of air).

If an adult individual were enclosed in an air-tight chamber 10 feet high, 10 feet wide, and 10 feet long—*i.e.*, in a chamber containing 1000 cubic feet of space—in an hour the CO_2 in this chamber would have had added to it 0·6 cubic foot of CO_2; the air originally contained 0·4 parts of CO_2 in 1000 parts, so that after one hour it would contain $0·4 + 0·6 = 1$ part of CO_2 per 1000, or $1 - 0·6 = 0·4$ per 1000 above the permissible limit of impurity. But if the subject of this experiment were enclosed in a chamber containing 3000 cubic feet of space, in one hour the amount of CO_2 would be only $\frac{3 \times 0·4 + 0·6}{3} = 0·6$ per 1000, *i.e.*, the limit would just have been reached, and at the end of a second hour, to keep the CO_2 down to this limit, 3000 cubic feet of fresh air from outside must have been allowed to enter the room. We thus see that an adult individual of either sex, when at rest, should be supplied with 3000 cubic feet of fresh air per hour.

By the equation $D = \frac{E}{r}$; where E = amount of CO_2 exhaled; r = respiratory impurity per cubic foot of air, and D = the delivery, or the amount of fresh air available in cubic feet; if E and r are known we can find D, or if D and E are known we can find r. If $E = 0·6$, and $r = 0·0002$, then $D = \frac{0·6}{0·0002} = 3000$. That is to say an adult requires 3000 cubic feet of fresh air per hour in order that the respiratory impurity may not exceed 0·2 per 1000, or—what is the same thing—the total impurity 0·6 per 1000.

*Example**.—If a room of 1000 cubic feet is occupied for 4 hours by 10 persons, each giving off an average amount of CO_2, what will be the total amount of CO_2 per 1000 volumes at the end of the time, supposing 10,000 cubic feet of fresh air per hour have been supplied?

In this problem D and *E* are given and we have to find *r*. The total amount of air available for breathing by the ten persons in the 4 hours is 1000 cubic feet (the cubic space of the room) + 10,000 × 4 cubic feet, (the amount supplied in 4 hours) = 41,000 cubic feet = D. The amount of CO_2 expired by 10 persons in 4 hours = 0·6 × 10 × 4 = 24 cubic feet = *E*.

$$D = \frac{E}{r} \text{ or } r = \frac{E}{D} = \frac{24}{41{,}000} = 0.00058,$$

i.e., *r* or the respiratory impurity is 0·58 parts per 1000. The total impurity, or the total amount of CO_2 in the air will be 0·58 + 0·4 = 0·98 pts. per 1000.

Example†.—The air of a room occupied by 6 persons, and containing 5000 cubic feet of space, yields 7·5 parts of CO_2 per 10,000 parts. How much air is being supplied per person per hour?

Here *E* and *r* are given and we have to find D. $E = 0·6 \times 6 = 3·6$ cubic feet CO_2 exhaled in one hour. $r = 7·5 - 4 = 3·5$ per 10,000, or 0·35 per 1000, or 0 00035 parts of CO_2 per cubic foot.

$$D = \frac{3·6}{0·00035} = 10{,}285,$$

* Sanitary Science Examination, Cambridge, 1880.

† Sanitary Science Examination, Cambridge, 1884.

but the room contains 5000 cubic feet of space, therefore in the first hour 5285 cubic feet of fresh air were supplied or 880 cubic feet per head. After the first hour to maintain the same amount of CO_2 in the air, 1714 cubic feet of fresh air would have to be supplied per head per hour.

During exertion a man gives off more respiratory impurities (CO_2, organic matters, moisture, etc.) than when at rest. For this reason the amount of air supplied to factories or workrooms should be considerably in excess—double or even treble, according to the nature of the work—of that required in an ordinary living or sleeping apartment. Some allowance, too, must be made for lights, especially gas-lights, when the products of combustion are allowed to escape into the air of the room. An ordinary small gas-burner, under a pressure equal to one inch of water, consumes about 3 cubic feet of gas in an hour, producing about 6 cubic feet of CO_2, or 10 times the quantity expired by an adult at rest, besides traces of sulphurous acid and other injurious gases, and much heat and watery vapour. It is true that no foul organic matters are given off in gas combustion; but still it is necessary to dilute and carry away these products of combustion, which take the place of the oxygen in atmospheric air, and are in themselves more or less injurious to health.

The amount of cubic space allotted to each person in a room is a matter of great importance; not because cubic space, however large in amount (as met with under ordinary conditions of inhabited dwellings), can take the place of a regular supply of fresh air from outside; but because the larger the cubic space, the easier it is to supply the proper amount of air without creating a draught. For instance, suppose, in a dormitory occupied by 10 persons, the amount of space per head is only 300 cubic feet; to supply 3000 cubic feet of fresh air per head per hour, 30,000 cubic feet must be admitted in this period, and the air of the room will be completely changed 10 times—a proceeding which would cause in cold weather, unless the entering air was warmed, a most disagreeable draught, for the cold air could not be properly distributed before reaching the persons of the occupants. But if the cubic space per head be 1000 cubic feet, then the air of the dormitory need be changed only 3 times per hour; and if such renewal is effected steadily and gradually, the cold entering air is broken up, and mixing with the warmer air of the apartment creates no draught.

A certain amount of superficial or floor space is necessary for each individual; for if the height of the room is much over 12 feet, excess in this direction does not compensate for deficiency in the other dimensions, although the total cubic space may be the same; thus it would not be the same thing to allow a man 50 square feet of floor space in a room 20 feet high, as to allow him 100 square feet of floor space in a room 10 feet high, although the amount of cubic space allotted in each case would be identical. The reason is that the organic matters of respiration are not equally diffused throughout the air of an apartment, but tend to accumulate in the lower strata; consequently excessive height does not, in their case, mean a corresponding dilution.

A few examples of the cubic and superficial space allotted under various conditions may be interesting. In common lodging houses in the metropolis, which are under police supervision, 30 superficial and 240 cubic feet of space are allotted to each adult over 12 years.

In workhouses 300 cubic feet are allowed for each adult in a dormitory; in military barracks about 600 cubic feet; in prison cells, under the separate confinement system, about 800 cubic feet with artificial ventilation; and in the best general hospitals about 1000 cubic feet of space for each bed, and 80 to 100 superficial square feet of floor space.

Natural ventilation.—During the colder months of the year in this country, a complete change of the air in an inhabited room, not greater than three times in an hour, is all that can be borne, when the entering air is not artificially warmed. Hence the importance of an allowance of cubic space not much less than 1000 cubic feet for each individual. The area of the inlet opening should be sufficiently large to allow the required volume of air (3000 cubic feet) to enter at a not greater speed than 5 feet per second, or about 3·4 miles per hour. This speed would be attained where the inlet opening for each individual was 24 square inches. During cold weather even this velocity could not be borne, and it may be said generally that efficient ventilation cannot be tolerated by anyone in cold weather, unless the entering air is artificially warmed. A velocity of the entering air of 2 to 3 feet per second is far more agreeable to the senses than a velocity of 5 feet; and if the air is artificially warmed to 60° F., the area of the inlet opening may be enlarged to 48 square inches for each individual, and the warmed air may then be supplied at a rate of $2\frac{1}{2}$ feet per second. This would be by far the most agreeable form of ventilation in cold weather. If the entering air is artificially warmed, the size of the inlet opening may even be increased up to 70 or 80 square inches per head, and the amount of cubic space may be diminished; for it would be possible then to change the

Q 2

air of the apartment more frequently than three times per hour without creating a draught.

Of the forces which act in natural ventilation, diffusion causes the gaseous impurities of respired air to mix with the fresh air in a room, until homogeneity is established. Diffusion, however, does not affect the suspended matters which tend to fall towards the earth in a still atmosphere; consequently organic matters in the air, which exist principally as minute solid particles, are not affected or removed by diffusion. No mechanical arrangements are needed to allow diffusion to take place.

The perflating action of the wind may be utilised by opening windows facing the wind, and the action is increased when windows, or a window and door on opposite sides of a room, are left open. The room is rapidly and continually flushed with air, an enormous effect being produced; for it is possible to renew the air of a room in this manner many hundred times an hour, even when the movement of the wind outside is only 2 miles an hour or 3 feet per second, equivalent to a very gentle breeze. Such a method is of unquestionable utility for rapidly changing the air of an unoccupied room, and may be generally put in operation in inhabited rooms in summer when the temperatures outside and inside the house approximate.

In any system of ventilation, however, that depends entirely on the wind, there is always the difficulty of regulating the velocity of the current according to the amount of movement of the air, and during complete calms the action is of course *nil.* The wind, too, often impedes ventilation by obstructing the passage of vitiated air from an exit shaft into whose mouth it blows; and this is not to be wondered at, for when blowing at the rate of 10 miles an hour, the pressure of the wind is half a pound on each square foot of surface.

For ventilating the holds and cabins of ships at sea, the wind may be most advantageously utilised. A large cowl, placed so as to face to the wind, conducts the air below by means of a pipe; whilst another, reversed so as to back to the wind, allows the used air to escape. By this exit shaft the aspirating force of the wind is utilised. Sylvester's system of ventilation proceeds on the same principles. A large cowl facing the wind is placed outside the house, and conducts the air to an underground chamber where it can be warmed if necessary by passing over hot water or steam pipes; it is then conducted to the rooms above by means of tubes, and finally escapes above the roof through tubes surmounted by cowls backed to the wind.

The aspirating action of the wind is constantly being used to ventilate rooms by means of the chimney. With a fire burning in the grate, the draught up the chimney is increased by the aspiration of the wind, when the top of the chimney is above surrounding buildings. Even when there is no fire in the grate, it will usually be found that there is a current setting up the chimney. Should the top of the chimney be lower than surrounding structures, the wind striking these and then descending, will often cause a back-draught and a smoky chimney. The remedy is evidently to carry up the chimney to at least the height of the surrounding buildings. A lobster-back revolving cowl surmounting the chimney, may prevent or mitigate back-draught; but it should be clearly understood that no sort of cowl that was ever invented can increase the up-draught in a chimney, no matter whether the top is overlooked or not by higher buildings in its neighbourhood. Another cause of smoky chimneys is an insufficient supply of air to the room. To feed the fire, air is drawn down the chimney, and coming down in puffs it causes an escape of smoke. The remedy is obtained by making a suitable inlet for fresh air into the apartment.

The movement produced by inequality in weight of masses of air at different temperatures is the natural force chiefly relied on for ventilating the interior of houses in this climate. This force is naturally chiefly called into action in cold weather, when the difference between the internal and external temperature is considerable, and is more or less in abeyance in summer, when the temperature outside is often equal to, or even higher, than that of the house. The greater this difference of temperature and the difference of level between the aperture for the entrance of cold air and the aperture for the exit of heated air, the greater will be the velocity of the entering air. We are enabled to calculate the theoretical velocity by means of Montgolfier's formula, which is founded on the dynamical law that the velocity in feet per second of falling bodies is equal to 8 times the square root of the height through which they have fallen. In this case the height fallen is represented by the difference in pressure of the air inside and outside the house, which is equal to the difference of level between the apertures of entrance and exit × by the expansion of air caused by the difference in temperature inside and outside.

$$v = 8\sqrt{\frac{(h - h')(t - t')}{491}} = \text{velocity in feet per second.}$$

Where h = height of aperture of exit from ground;
,, h' = ,, ,, entrance from ground;
,, t = temperature of air inside in degrees Fahr.;
,, t' = ,, ,, outside in degrees Fahr.;

In practice an allowance for friction of $\frac{1}{4}$ or $\frac{1}{2}$ must be made. If the area of the inlet opening is known, the amount of air entering the room in a minute or hour can easily be calculated by multiplying the velocity by the area of the inlet expressed as square feet, or as a fraction of a square foot.

In a room as usually constructed with sash windows and with a fire-place and chimney, but without any special means of ventilation, when a fire is burning in the grate the heated air of the room in part ascends the chimney flue, and in part rises to the ceiling. Cold air from outside will then enter—if the windows are closed—under the door, under the skirting boards, between the sashes of the window, and through any other chinks or apertures due to loose fittings. The bricks and plaster of the walls are also porous to a certain extent, and if uncovered by paint or wall-paper will admit a small quantity of air. Thus a large volume of air may be entering a room in cold weather when the fire is burning, although there are no visible inlets; and the amount of air thus supplied may be sufficient for the needs of two or three persons if it were properly distributed. But such is not the case. The cold air, which enters chiefly near the floor, takes as straight a course as possible to the fire-place, producing a disagreeable draught to the feet of the occupants, whilst the heated and vitiated air near the ceiling is left undisturbed.

It has been found practically that to prevent draughts and to ensure a thorough distribution, fresh air should be admitted into a room above the heads of the occupants, an upward direction being given to it so that it may impinge on the ceiling, mix with and be warmed by the heated air in this situation, fall gently into all parts of the room, and be gradually removed by means of the chimney-flue or any other outlet, which should preferably be at the highest part of the room.

Amongst simple contrivances for windows by which these objects may be attained, may be mentioned

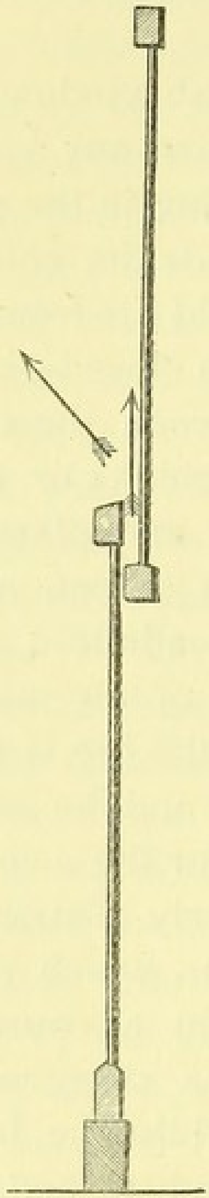

FIG. 32.—Hinckes-Bird's Window Ventilator.

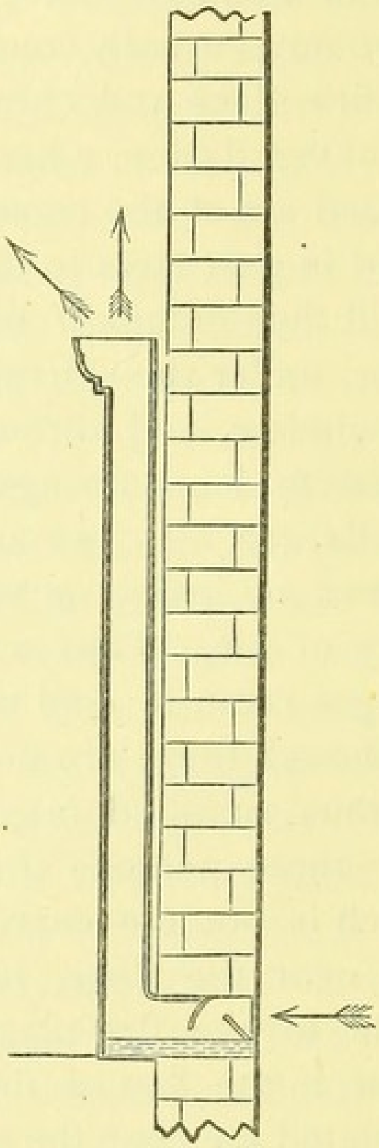

FIG. 33.—Tobin's Tube with Water Tray.

Hinckes-Bird's method (fig. 32) now so well known, of placing a solid block of wood under the entire length of the lower sash frame of a window, so as to raise the top of the lower sash above the bottom rail of the upper sash. By this means the air is admitted between the two sashes above the heads of the occupants of the room, and is given an upward direction towards the ceiling. Holes bored in a perpendicular direction in the bottom rail of the upper sash, louvred panes (fig. 34) to replace one of the squares of glass, an arrangement for allowing one of the squares of glass to fall inwards upon its lower border and providing it with side checks, or a double pane of glass in one square, open at the bottom outside and at the top inside, all effect the same

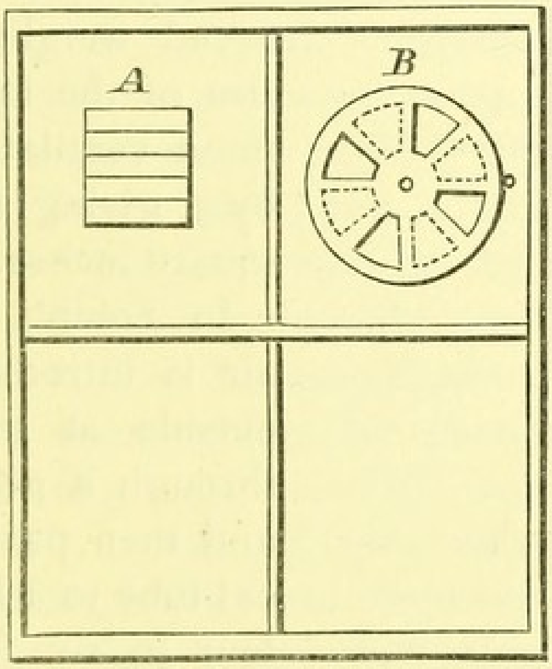

FIG. 34.—Window Ventilators. *A*. Louvre. *B*. Cooper's.

purpose and are simple and inexpensive contrivances. Cooper's ventilator (fig. 34), which consists of a series of apertures in the glass of a window pane, arranged in a circle so as to be capable of being more or less completely closed by a circular glass disc with corresponding apertures movable on a central pivot, does not admit the air in an upward direction, but breaks it up into a number of divided currents, thus lessening the tendency to draught. The same object can be attained by placing wire gauze or muslin over any inlet opening.

The most generally used wall-inlet ventilators are Sheringham's valve, Tobin's tube, and Ellison's conical bricks.

In the Sheringham's valve (fig. 35) air passes through the wall by means of a perforated iron plate, and is then directed upwards by a valved plate with side checks, which, being hinged at its lower border, is capable of being more or less completely closed by a balanced weight. The usual size of the inlet opening in these ventilators is 9 inches by 3, giving an area of 27 square inches.

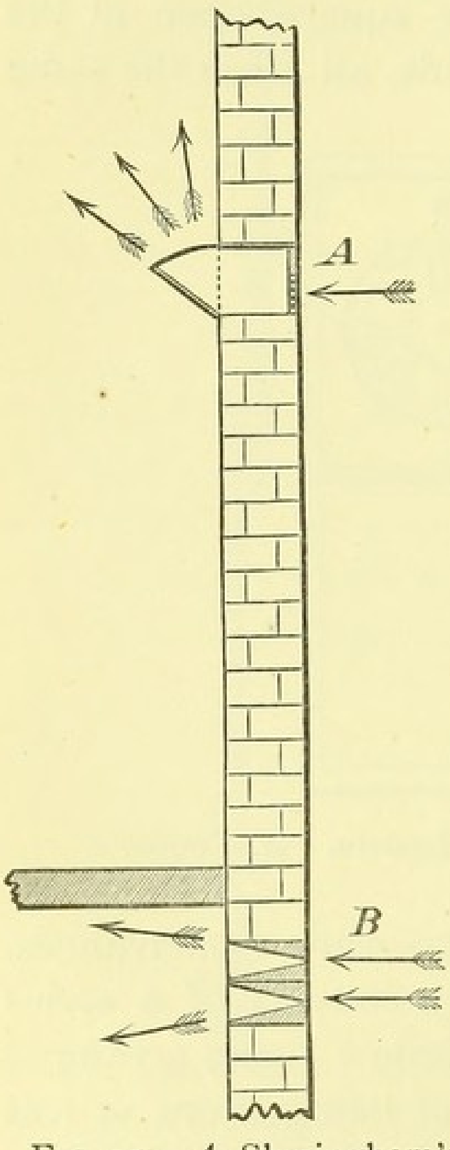

FIG. 35.—*A*. Sheringham's Valve. *B*. Ellison's Conical Brick Ventilators.

In Tobin's tube (fig. 33) air is introduced from the outside at the floor level through a perforated plate, and then passes up a vertical tube to a height of from four to six feet above the floor. After escaping from the tube the current of air ascends more or less vertically for several feet, before it begins to spread out and mix with the air of the room. In these two contrivances (Tobin's tube and the Sheringham's valve) the entering air may be filtered through muslin or cotton wool, or made to impinge upon a tray containing water, and so deposit its sooty particles—a procedure often advisable in smoky towns.

Ellison's bricks (fig. 35) are pierced with conical holes; the small opening, $\frac{1}{5}$ inch in diameter, being placed outside the house, whilst the larger opening, $1\frac{1}{4}$ inch in diameter, is placed inside. The thickness of the brick is $4\frac{1}{2}$ inches. The air passing through these conical apertures becomes widely distributed in every direction; and in this way its entrance is rendered imperceptible and unproductive of draught.

All the inlet ventilators now described are intended to utilise the movements produced by masses of air in contiguity being at unequal temperatures. For this reason they should be protected as far as possible from the perflating action of the wind. This cannot, however, always be done; and when a strong cold wind is blowing into a ventilator, even of the most approved sort, a most unbearable draught is the result. To obviate this, there should be some means of controlling the amount of entering air by partially closing the ventilator, and in many cases the ventilator must be closed altogether. Sheringham's valve, Tobin's tube, and louvred inlets, fulfil these requirements very satisfactorily. It is often found that inlet ventilators are acting as outlets for the escape of air, when fresh air is entering a room from other sources. This cannot be obviated, nor indeed is it necessary. All that can be done is to place the inlets in the best possible position for distributing the entering air throughout the apartment without causing a draught, and to close up all such sources of entering air as are productive of draughts.

The usual outlet for the vitiated air of a room is the chimney flue; and this, for an ordinary medium sized sitting-room, with a fire burning in the grate, is sufficient for three or four people, provided no gas is alight, or the gas lamp has its own special ventilating arrangement. With an ordinary fire, from 10,000 to 15,000 cubic feet of air are drawn up the chimney in an hour. Heated air rises to the top of a room, therefore the proper place to admit of the vitiated air escaping is in or near the ceiling.

Neil Arnott's or Boyle's valves (small talc plates), which open into the chimney flue near the ceiling, are sometimes used as outlets for foul air. They permit air to pass into the flue, but prevent its return; the objections to their use are that they occasionally permit the reflux of smoke into the room, and their movements backwards and forwards produce a slight clicking noise. If exit shafts other than the chimney flue are provided, they should be short and straight; otherwise friction, and loss of heat by passage of the air through an exposed tube, will stop the current altogether, or reverse it, causing a back-draught. The escaping air must have its temperature kept up, or it will become cooler than the air of the apartment.

One of the best methods of attaining this object, which might be put in practice in all new buildings, is to construct a shaft at one side of, or surrounding the chimney flue, with an inlet near the ceiling of the room, and the outlet at the level of the chimney top. The air escaping from the room will then have its temperature kept up by contact with the chimney flue, thus aiding the updraught, whilst the risk of reflux of smoke will be avoided. The air flues may be moulded in the same piece of fireclay as the smoke flue; but those from different rooms should not be connected in any way, or foul air from one room might pass into another.

The combustion of gas may be made a very effective means of getting rid of foul air. It has been found by experiment that the combustion of one cubic foot of coal gas causes the discharge of 1000 cubic feet of air. An extraction shaft may be placed over a gas lamp or chandelier, or by means of a Benham's ventilating globe light, or a Mackinnel's ventilator, slightly warmed fresh air may be admitted at the same time as foul air is extracted.

Mackinnel's ventilator (fig. 36) is very useful for a room which has no other apartment over it. Two

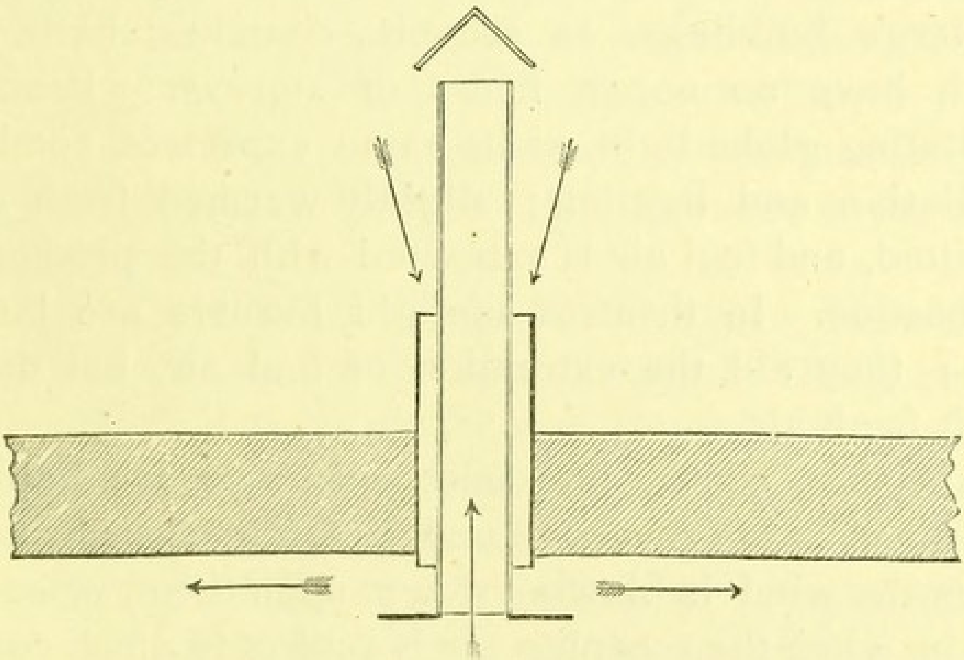

FIG. 36.—MacKinnel's Ventilator.

tubes, one inside the other, are carried through the ceiling or roof of the building. The inner one, which is for the extraction of foul heated air, projects outside above the outer, and inside also below it. At its lower end a circular horizontal rim is attached to the inner tube which deflects the air entering by the outer tube, and causes it to pass for a short distance parallel to the ceiling before falling into the room. The gas burners or lamps used to light the room may be placed immediately under this ventilator. The inner or extraction tube should have its top protected by a cover or cowl, to prevent the wind blowing down and the entrance of rain, which by evaporation might so cool the escaping air as to cause it to be heavier than the air of the apartment. The entering air will be slightly warmed by its passage over the heated extraction shaft. The area of the outer tube for the passage of fresh air should be equal to, or slightly larger (for there is more friction to overcome) than the area of the inner tube for exit of foul air. Mackinnel's ventilator is well adapted for large buildings, as schools, churches, halls, etc., which have no upper floors or storeys. Benham's ventilating globe light, as its name expresses, combines ventilation and lighting; slightly warmed fresh air is admitted, and foul air is extracted with the products of combustion. In theatres sunlight burners are largely used; they aid the extraction of foul air, but do not admit fresh air.

Extraction shafts, like inlet openings, are liable to have their action reversed under certain circumstances. When the wind is blowing down upon them, when rain gets in, when the escaping air is subject to much cooling in an exposed shaft, or when there are more outlets than one in a room, one predominating over the others, down draughts are likely to occur. This most frequently happens when the draught up the chimney is very great from there being a large fire burning; then there is a tendency for every other opening into a room to become an inlet. Also, when the wind is blowing down an exit shaft or chimney flue, the windows or inlet ventilators may become outlets. These matters can, however, generally be regulated by attention to the facts and principles which have been already laid down as a guide to proper ventilation.

It will be convenient to mention in this place some facts with regard to loss of velocity in air shafts by friction. The actual loss can in some cases be determined by calculating the theoretical velocity in an air shaft by Montgolfier's formula, and then ascertaining practically by means of a current meter or anemometer the actual rate at which the air is issuing or escaping. The difference represents the loss due to friction; but allowance must of course be made for disturbing forces such as the perflating or aspirating action of the wind. Contrasting two similar tubes of equal sectional area, the loss by friction will be directly as the length of the tube. If the two similar tubes are of unequal size, the loss by friction is inversely as the diameter of the cross section in each.

When two tubes are dissimilar in shape, the loss by friction is inversely as the square roots of the sectional areas. A circle is the figure which includes the greatest area within the smallest periphery; thus, if there are two tubes, one of which is circular on section and the other square, but having the same area (1 square foot), the loss by friction is directly as the periphery, and in this case is as $\frac{3\frac{1}{2}}{4}$, the periphery of the square being four feet and of the circle $3\frac{1}{2}$ feet. Every right angle in a bent shaft diminishes the velocity of the current one-half. It will thus be seen that air shafts should preferably be circular in section, short, and straight, so as to diminish the loss by friction as far as possible. The absurdity of ventilating soil-pipes and drains by narrow pipes, 1 inch or less in diameter, of great length, and bent on themselves often to a right angle, is apparent from the above statements. The ventilation of drains is always difficult to establish; carried out by such methods it becomes an impossibility.

Ventilating appliances whose object is the supply of artificially warmed air, will be considered separately in the chapter on *Heating and Warming*.

Artificial Ventilation.—Under this heading are usually described methods of extraction of air from inhabited buildings by means of heat, steam, or fans; and methods of propulsion of air into buildings by mechanical means. It has been found convenient to describe under natural ventilation of rooms the ventilating effects produced by fires and chimneys in ordinary rooms; and the extractive properties of gas lights have been also alluded to, although more properly fires and gas are artificial means of ventilation.

The fire and chimney of an ordinary sitting room are types of the methods used on a larger scale for extraction by heat. The principle is the same in all and depends on the heating of a column of air in an extraction shaft, which being thus made lighter ascends; as long as the heat is applied, a continual current of air towards the shaft is produced, which in its turn being heated, ascends and escapes, to be replaced by more from below.

It is in this way that some mines are ventilated. The underground workings and galleries of the mine are connected with two large shafts leading to the open air—an upcast shaft and a downcast shaft—in such a manner that, if air is made to pass down the downcast or intake shaft, it has to travel through all the workings of the mine before it can escape by the upcast or return shaft.

The power which produces this continued movement of air is supplied by a furnace at the bottom of the upcast shaft exerting an extractive force by the heated column of air, as previously described. In many mines the extractive force is exerted by means of a powerful rotary exhaust fan placed at the top of the upcast shaft. Numerous doors and partitions are necessary in the galleries and workings, in order to make the air traverse the whole length of these, and prevent its taking short cuts. An enormous volume of fresh air must be passed through a mine in the course of every hour in order to supply the quantity necessary for the respiration of the men and ponies employed underground, and to withdraw the products of combustion of lights (lamps and candles) and gunpowder blasting, and replace these injurious gases by pure air.

Where fire-damp (CH_4) is evolved from the strata cut through, the ventilation must be even in excess of these requirements, in order to dilute this gas sufficiently to prevent its forming an explosive compound with atmospheric oxygen. The same may be said with regard to the evolution of carbonic acid from the rocks underground, which so frequently takes place. This gas must not be allowed to form more than a certain percentage of the underground air, or its asphyxiating properties will be exerted on all animal life within its influence. The injurious effects produced by gunpowder blasting, which have been already mentioned (p. 208), as the result of the evolution of so many poisonous gases into the air, are no longer necessary evils in the life of the collier or coal miner since the introduction of cartridges made of quicklime, which swell up from slaking when water is run over them, and exert their action without producing any gas at all. By the use of such cartridges there is besides no risk of explosion from ignition of fire-damp. Other substitutes for explosives in fire-damp collieries are plugs of dry wood, which swell when wetted, wedges worked by hydraulic pressure, and cartridges containing compressed air at extremely high pressures.

Dynamite is now largely used instead of gunpowder, as it is more powerful, may be used under water, and requires no hard tamping. It is a mixture of nitroglycerine $C_3H_5 3(NO_3)$ and infusorial earth or kieselguhr. Carbonic oxide is not one of the products of its explosion under pressure; and hence its superiority to gunpowder, in which carbonic oxide forms 7½ per cent. of the explosive gases. There is besides no formation of sulphuretted hydrogen and marsh gas when dynamite is exploded. These gases form respectively about 2 per cent. of the total gases resulting from gunpowder explosion. Carbonic acid and nitrogen form nearly the entire bulk of the gases resulting from nitro-glycerine explosion in closed vessels. Nitrated gun-cotton and blasting gelatine (nitro-cotton and nitro-glycerine) are also superior to gunpowder for the same reasons; carbonic acid and nitrogen forming almost the entire bulk of the gases generated when these substances are exploded under pressure.*

Notwithstanding the importance of an abundant supply of pure air to all the workings of a mine, it has been found impossible by the Government Inspectors to insist on a greater standard of purity than that indicated by 0·25 per cent. of CO_2 in the air. It is said that in every mine at least 6000 cubic feet of fresh air per hour should be supplied for every man employed below, for if this quantity is much reduced, there is a serious diminution in the amount of work performed by the men, so that even commercially it pays employers to have adequate ventilation. In mines where fire-damp

* *Encyclopædia Britannica*—Article on "Mining," by C. Le Neve Foster, D.Sc.

or choke-damp are evolved, the amount of fresh air supplied should exceed this figure. The upcast and downcast shafts in collieries are usually from 8 to 12 feet in diameter; the furnace at the bottom of the upcast shaft must be regulated according to the number of men employed and the amount of work that is going on at any time below ground.

Public halls, hospitals, and other large buildings are sometimes ventilated on the extraction principle. Shafts for the escape of vitiated air lead from the different rooms and open into the chimney just over the furnace. The air from these shafts should not be used to supply the fire or furnace, but should open into the flue just above it, where the draught is greatest.

The column of air in the extraction shaft may be heated by hot-water pipes instead of by a fire. This is the plan adopted at the Hôpital Lariboisière in Paris. The extraction shaft is heated throughout the greater part of its length by spiral hot-water pipes coming from a boiler in the basement. These hot-water pipes are also carried into the wards, where they are coiled so as to warm the fresh air entering from without; they then return to the boiler, and thus complete the circuit. The tubes from the wards for the escape of foul air open into the bottom of the extraction shaft. In summer, the circulation of hot water in the pipes in the wards is stopped, the circuit being completed by return pipes from the top of the extraction shaft, so that the ventilation continues, but the air entering the wards is not artificially warmed. The column of air in the extraction shaft may be heated by gas instead of by fire; but this method is more suitable for the smaller tubes used as exit shafts in ordinary sized dwelling-rooms. Foul air may also be extracted by passing a steam jet into a chimney or upcast shaft. The cone of steam emitted from a boiler is said to set in motion and drive before it a body of air equal to 217 times its own bulk. The shafts for the escape of foul air must open into the extraction shaft below the steam jet.

On board steamships and men-of-war it has been found that very effective ventilation can be attained by causing the furnaces to extract the air from all parts of the ship through special shafts. By this means also, if the boilers and steam apparatus are enclosed in iron casings, as far as possible, within which the air shafts open, the temperature of the stoke hole is greatly reduced.

Some of the chief objections to the method of extraction by heat are (1) where the heat is produced by a furnace, it is most difficult to keep this at a constant height, consequently the draught is often very irregular. This difficulty is not encountered where the extraction shaft is heated by gas or hot water pipes, or where the air in it is forced upwards by steam. (2) In all cases where a number of air conduits from rooms at different distances open into an extraction shaft, there is a great tendency to create powerful currents from rooms that are near, and have short conduits leading from them; whilst from the distant apartments with long and perhaps much curved conduits, the current may be very slight or even *nil*. This difficulty may to a certain extent be overcome by increasing the diameter of the longer pipes so as to reduce the friction, and by bending the shorter pipes so as to increase it; but in practice it is a rather serious drawback. (3) When air is drawn out of a room it is somewhat difficult to control the entrance of fresh air to supply its place, especially with regard to its points of entry, and its exclusion from places such as

W.C's., from which it is most desirable that no air should be taken.

In the ventilation of factories, steam may often be economically and usefully applied as the extraction force, but extraction by fans has also been largely used, and presents considerable advantages, as the amount of draught can be nicely regulated by altering the speed (the number of revolutions per minute) at which the fan is driven. It is especially in the textile trades—in the cotton, woollen, silk, worsted, and flax factories—that ventilation is most urgently needed. In many of the processes of these manufactures the work is not only carried on in clouds of dust, but also in greatly heated atmospheres which are saturated with moisture, this being necessary in some instances to the proper performance of the work. To carry off the floating particles of dust it is necessary to induce a powerful current in the exit shaft, so that the air may be drawn in as if to a vortex. In some cases the opening into the exit shaft may be in the centre of the room; but it is more often advisable to carry the dust away as soon as it originates, and before it can mix with the general air of the apartment.

Thus in the wool-sorting trade, each bench on which the wool is sorted has an opening leading by means of a pipe into the extraction shaft, at the extremity of which the exhaust fan is working. When the wool is being shaken, the dust, amongst which may be the spores of bacilli anthracis, is drawn into the tube and does not mix with the air which is inhaled by the workman. The dust is then blown into settling chambers, where it is damped by steam jets, and so deposited can be collected and burnt. In silk-dressing processes, air tubes are placed above the machinery with dependent hooded openings, which cover the area of dust production and quickly remove it. In the dry grinding processes of the metal trades, the air tubes are placed level with the grindstones and have openings opposite each stone, in such positions as to catch the dust, as it is driven off, and carry it away at once. The best material for the exit shafts or tubes is galvanized sheet iron, as it can be made into smooth circular pipes. Arrangements must be made to provide that the draught from the benches or workrooms nearest the fan is not so great as to prevent the shafts at a distance from working properly.

A very convenient form of fan is that known as the Blackman Air Propeller; it can be used for exhaustion or for propulsion, and is very powerful in its action, its vanes being large and curved. It can be driven by a gas engine. When used for propelling air into a building, the rate of movement in the main conduit should not exceed 5 feet per second, and, where delivered into the rooms, not more than $1\frac{1}{2}$ or 2 feet per second.

Ventilation by propulsion presents several advantages. The amount of air delivered and the rate of movement can be regulated with nicety, and the entering air can be taken from any point desired, can be warmed, cooled by a spray of water, or filtered through muslin or cotton wool in special chambers.

In the Houses of Parliament at Westminster a combined method of ventilation by propulsion and extraction by heat is in operation. Air is propelled by rotatory fans along conduits to the basement, where it is warmed in winter by passing over steam pipes, and then passes upwards through shafts into the space beneath the grated floor of the House. The heat can be regulated by covering the steam pipes with woollen cloths, and in summer the entering air can be sprayed with water or cooled by passing over ice in the conduits. The vitiated air in the House passes through a perforated glass ceiling in the roof, and is then conducted by a shaft to the basement of the clock tower, where it passes into the flue of a large furnace.

In Verity's system air is set in motion by a spray of water from a number of very fine jets. The rate of motion can be regulated by the tap which supplies the jet. The method is useful for houses where it is not desired to go to the expense of fans driven by machinery.

Some system of artificial ventilation with a supply of warmed fresh air is especially necessary for schoolrooms, where the amount of cubic space per head is often very limited. The English Education Department requirements are only 100 cubic feet of space per scholar, and 10 square feet of floor space. These are the minimum requirements; but even with double these amounts, ventilation by natural means in cold weather would be productive of draughts and great lowering of temperature in the room. Dr. Newsholme is of opinion that good average requirements for schools are, for each scholar, 150 cubic feet of space, 15 square feet of floor space, and 1500 to 1800 cubic feet of fresh air per hour.

Practical Examination of the Ventilation and Air of Inhabited Rooms.

In the first place it is necessary to determine the amount of cubic space. In rooms of regular shape this may be done by multiplying together the three dimensions of height, length, and breadth. If the room is irregular in form, containing recesses and projections, or with a raised ceiling, it is usually most convenient to divide it up into a number of simple parts, whose cubic contents can be determined by some one or more of the following rules:—

Area of circle = square of diameter (D^2) × 0·7854.

Circumference of circle = D × 3·1416.

Area of ellipse = the product of the two diameters × 0·7854.

Circumference of ellipse = half the sum of the two diameters × 3·1416.

Area of square = square of one of the sides.

Area of rectangle = the product of two adjacent sides.

Area of triangle = base × $\frac{1}{2}$ height.

Area of any figure bounded by straight lines = divide into triangles, and take the sum of their area.

Area of segment of circle = $(Ch \times H \times \frac{2}{3}) + \frac{H^3}{2Ch}$

Ch = chord, H = height.

Cubic capacity of cube or solid rectangle = length × height × breadth.

Cubic capacity of solid triangle = area of triangle × height.

Cubic capacity of cylinder = area of base (circle) × height.

Cubic capacity of cone or pyramid = area of base (circle) × $\frac{1}{3}$ height.

Cubic capacity of dome = area of base (circle) × $\frac{2}{3}$ height.

Cubic capacity of sphere = D^3 × 0·5236.

Thus supposing it was required to determine the cubic capacity of a circular hospital ward 30 feet in diameter, 10 feet high, and with a dome shaped roof 5 feet high.

The area of the base or floor space is 706·86 square feet. The cubic capacity of the cylinder below the dome is 706·86 × 10 = 7068·6 cubic feet, to which must be added the cubic capacity of the dome = 2356·2 cubic feet. So that the cubic capacity of the ward is 9424·8 cubic feet. Deductions must be made for the larger pieces of furniture, such as beds, cupboards, wardrobes, etc., and for the number of occupants of the room, each of whom, if adults, may be taken as occupying about 3 cubic feet of space.

Having determined the cubic space, the next point is to take note of the direction of the movement of air through the various openings into the room. This may best be done by observing the direction given to the smoke evolved from smouldering brown paper or cotton-velvet, when held close to the apertures, some of which will be found to act as inlets and others as outlets. The rate of movement of air through these apertures may be approximately ascertained by placing in them an anemometer, which is an instrument consisting of 4 little revolving sails driven by the wind or current of air. The sails turn an axis with an endless screw running on small toothed wheels, which, by means of a plate and dial, indicate the number of revolutions of the axis and the space traversed by the sails. By experiment with air moving at a known rate of speed, the anemometer may be graduated. It appears, however, that even tested anemometers are subject to variations, and too much reliance must not be placed on their indications. A modification of the water manometer, or pressure guage, is occasionally used. The current of air impinges on the surface of the water in one arm of the bent tube, and in proportion to its strength drives the water up the other arm, which is inclined at a certain angle. The records obtained in this manner can be compared with the theoretical velocities obtained by the use of Montgolfier's formula, allowances being of course made for friction and wind. When the wind is at all strong and is blowing directly into inlet ventilators, or is exerting a powerful aspirating action on chimneys or exit shafts, calculation is useless.

Estimation of Carbonic Acid in Air—Pettenkofer's Method. A glass stoppered vessel of known capacity (2 litres is a convenient size) is filled with mercury and emptied in the place, the air of which is to be examined, or air may be forced into the bottle by means of a bellows; 60 c.c. of clear lime or baryta water are then introduced into the vessel; the mouth is closed and the bottle, after being well agitated, is allowed to stand for some hours. Some portion of the lime or baryta combines with the CO_2 in the air of the vessel. The causticity of the lime or baryta solution is consequently lessened. Supposing lime water to be used in the experiment, its causticity must be previously determined by means of a standard solution of crystallised oxalic acid (see Appendix), 1 c.c. of which exactly neutralizes 1·26 milligramme of lime (= 0·5 c.c. of CO_2). The exact point of neutralisation can be determined by turmeric paper. By this means the number of milligrammes of lime in the 60 c.c. of lime water used in the experiment can be determined. After the bottle has stood for a few hours, 30 c.c. of the lime water should be withdrawn and again tested with oxalic acid solution, and the loss of causticity, representing the number of milligrammes of lime which have combined with the CO_2 of the air, noted.

Example.—In a jar of capacity 2000 c.c. (2 litres), it is found that 30 c.c. of lime water, after standing 8 hours, have lost causticity represented by 10 c.c. of the oxalic acid solution. Therefore the 60 c.c. of lime water introduced have lost causticity represented by 20 c.c. of the oxalic acid solution, equivalent to 10 c.c. of CO_2.

2000—60 (= 1940) c.c. of air in the jar are thus seen to contain 10 c.c. of CO_2, and 1000 c.c. contain 5·15 c.c. of CO_2; or the CO_2 is present to the extent of 5·15 parts per 1000, or 0·515 per cent.

If the air of the room is above 32° F., a correction must be made by adding 0·2 per cent. to the result for every degree above freezing point. A correction for height above sea level may be made, if the place is in a mountainous district, by a simple rule of three from the observed height of the barometer.

Estimation of Organic Matter in Air.—The simplest method is to draw a measured volume of air to be examined, by means of an aspirator, through a wash-bottle, or a succession of wash-bottles, containing distilled water free from ammonia. The water absorbs the organic matters or a portion of them, and it can then be submitted to analysis for free and albuminoid ammonia according to Wanklyn's method. The results can be expressed as milligrammes of ammonia and albuminoid ammonia per cubic metre (= 1000 litres) of the air examined. They are necessarily indications only of the amount of nitrogenised organic matter in the air. The oxidisable matters in air, including putrescible organic matters, sulphuretted hydrogen, nitrous acid, and tarry matters, may be determined by submitting a part of the water used in the above experiment to the permanganate of potassium test. What has been said in the chapter on examination of water (p. 82) applies equally to the test as now proposed for the estimation of oxidisable matters in air.

Microscopical Examination of Suspended Matters.—In Pouchet's aeroscope air is drawn through a glass funnel narrowed to a fine point, which just rests upon a drop of pure glycerine on a glass slide. The funnel and slide are enclosed in an air-tight bottle or box, which is connected by tubing with an aspirator, the open mouth of the funnel projecting above the top of the bottle or box. The suspended matters are caught in the glycerine and can be examined with an immersion lens.

Another method is to immerse a bent glass tube, previously heated to redness (to sterilise it), in a freezing mixture of salt and ice, and to slowly aspirate air through it. The moisture of the air is condensed into drops in the lowest part of the bend, entangling suspended matters with it, and a drop of this fluid can be examined microscopically.

Examination of Air for Bacteria, *Fungi*, and *Moulds.*—Hesse's apparatus is the most convenient. It consists of a hollow glass cylinder, one end of which can be closed with an india-rubber cap, whilst the other is connected with an aspirator. All parts of the apparatus having been cleaned with corrosive sublimate solution and then with alcohol, 50 c.c. of nutrient gelatine are introduced into the cylinder, and the whole sterilised by steaming for half-an-hour on 3 successive days. After the final sterilisation, the cylinder is rotated on its long axis, so that the gelatine solidifies in the form of a coating over the whole of the interior. The india-rubber cap is now removed from one end, while the other is connected with the aspirator, and the apparatus is ready for use. As the air is drawn slowly through, spores and germs fall on the gelatine, and colonies, visible to the naked eye, are formed in a few days, and may be counted. It is usually found that the colonies of moulds and fungi are formed further from the mouth of the cylinder than the bacterial colonies—it thus appearing that the spores or germs of these organisms can be carried greater distances through the air than the bacteria. In pure air it would seem that the moulds and fungi are present relatively in larger numbers than the bacteria, whilst in air vitiated by respiration or organic effluvia of various kinds the reverse is the case.

CHAPTER IV.

WARMING AND LIGHTING.

Warming.

In all cold climates means are provided for heating the interior of houses. It is a very difficult matter to supply a satisfactory degree of warmth for everybody, as individual susceptibilities to heat and cold are so various, depending as they do upon age, sex, robustness of constitution, and previous habitude. It may, however, be permissible to state that as a general rule, the temperature of a sitting-room or work-room should be about 60° F. to 65° F. The clothing of the individual should be so adjusted that a position of rest at this temperature in a well-ventilated room free from draughts shall cause neither a sensation of chill nor a feeling of undue heat.

Whilst this degree of warmth (60° to 65°) may be regarded as a suitable one for the average healthy individual, in the extremes of life—in infancy and old age—and in cases of sickness, a higher temperature reaching up to 70° is often desirable.

Radiation.

In this country houses are generally warmed by radiant heat from open fire-places. By radiation is meant the passage of heat from warm bodies to cold ones, the rays of heat passing through the air but without warming it. This form of heat is no doubt the most healthy, for whilst objects within the range of the fire are heated, no impurities are added to the air of the room. It is, however, extremely wasteful, for the greater part of the heat ($\frac{5}{8}$ at least) escapes up the chimney. The column of air in the chimney-flue is heated, and, becoming lighter than the external air, escapes at the roof of the house to be replaced by colder and denser air from below. An open fire, therefore, as we have seen in the chapter on ventilation, acts as a powerful ventilator.

The intensity of radiant heat is inversely as the square of the distance of the heated object from the source of heat. Thus if there are two objects, 1 foot and 3 feet distant respectively from an open fire-place, the more distant object only receives $\frac{1}{9}$ the amount of heat received by the nearer object. This fact shows the impossibility of warming equally all parts of a room, when the source of heat is an open fire-place.

Of late much has been done to improve open fire-places by securing the greatest amount of heat production with the least consumption of fuel. Some of these improvements have been made at the suggestion of Mr. Pridgin Teale. They may be thus summarized:—

The width of the grate at the back should be about one-third the width in front facing the room, the sides of the grate being sloped out at the necessary angle. The back and sides of the grate should be formed of fire-clay, and the back instead of rising perpendicularly should be "rifle-backed," *i.e.*, curved forward so that the flames may play upon it (fig. 37). The curved portion becomes heated by some of the upward rays, which would otherwise be lost up the chimney, and radiates this heat into the room.

The floor of the grate should be formed of a solid slab of fire-clay; or if the lower fire-bars are retained, a shield should be placed on the hearth, rising as high as the bottom bar of the grate, so as to form a hot-air chamber under the grate completely closed off from the air of the room (fig. 37). The object of this arrange-

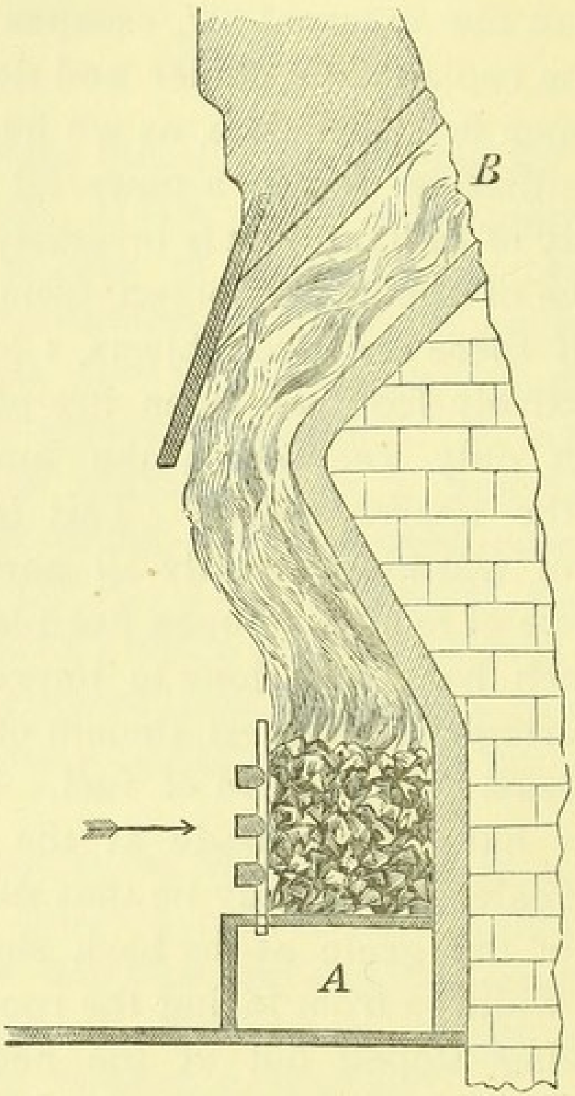

FIG. 37.—Rifle-backed Stove with Economiser.
A. Hot Air Chamber. *B*. Flue.

ment is to check the bottom draught under a fire, which causes too quick combustion and waste of fuel.

The whole fire-place should be brought well forward into the room, and the chimney throat should be narrowed as much as possible.

Open grates of this description create much smoke, as the combustion of the fuel is by no means complete. Attempts have been made to construct a smokeless open grate, and the plan which has been found on the whole to answer the best is to "underfeed" the fire, by which is meant that the supply of fresh fuel is introduced beneath the incandescent coal which forms the top of the fire, and through which the gases arising from the fresh coal must pass, thus securing complete combustion.

In one of the best of these smokeless fire-places, a curved ledge projects from the bottom of the grate. The fresh fuel is placed on this ledge and forced under the blazing coal above by means of a special kind of shovel. These "underfed" grates are found to be very efficient heaters for the amount of coal consumed, and they continuously expose a clear fire free from smoke, but they require more care in stoking and management than ordinary grates.

Wherever possible, fire-places and chimney-flues should be built in one of the inner walls of a house. The waste heat of the flue will then serve to warm the upper rooms at least, and the total loss will be less considerable than in the case of fire-places built in an outer wall. It is evident that as open fire-places act as ventilators for extraction of air, to carry on this function, the column of air in the flue must be kept continuously heated, otherwise the chimney will not "draw," and back-currents of smoke enter the room. In an ideal stove, the heat escaping up the chimney should be not more than sufficient to maintain a good draught, the rest being radiated into the room.

With a reduction in the price of coal gas, open gas-fires have come more largely into use. As usually constructed, the flames from a row of Bunsen burners play upon asbestos in lumps or fibre, which is heated to a red heat. Until gas is supplied at 1*s*. or 1*s*. 6*d*. per 1000 cubic feet, which could easily be done if it were freed from illuminants, or until a public supply of *water gas* is made available, gas-fires must be more expensive than coal. But they have the advantage of being very cleanly—there is no soot in the chimney-flue and no dust or ashes—very convenient, and causing no trouble. As regards the prevention of smoke, the more extended use in our large towns of coal gas for heating and cooking, would undoubtedly tend to free the air from much of the soot and smoke that now pollute it. Fogs, which depend so largely upon climate and site, would be just as frequent, if less sooty and yellow. They would also be as sulphurous, for the sulphur compounds are produced by gas and coal combustion alike, and we can never hope to eradicate sulphurous acid from the air so long as we use coal or its derivatives as our only fuel.

It is highly probable that *water gas* will in process of time come largely into use for heating and illuminating purposes—for gas-fires and gas-cooking stoves, and for incandescent burners. Water gas is produced by passing steam through incandescent coke or other carbonaceous matter, raised to a high temperature in a "generator" furnace by the aid of an air-blast. The incandescent coke gives off what is known as "producer-gas," and this is led away from the generator before the steam is introduced. The introduction of the steam is only continued for about four minutes, after which time it is necessary to turn on the air-blast again to re-heat the coke. It will thus be seen that the process consists of alternately blowing the generator hot (for 10 minutes), when producer-gas is formed and led away, and of making water gas by introducing steam over the hot fuel (for 4 minutes). The water gas, as formed, is passed over scrubbers and purified over oxide of iron, in much the same way as coal gas, before being stored in gas-holders: it then consists almost entirely of hydrogen gas. In heating power water gas is far superior to coal gas; and as the only product of combustion is H_2O vapour, the injurious CO_2 and SO_2 products of combustion of coal gas are avoided. Water gas, too, can be produced very cheaply, viz., at about 4*d.* per 1000 cubic feet. The "producer-gas," consisting largely of carbonic oxide, is used for heating the boilers which generate the steam.

It is perhaps needless to point out that plumbers should never be allowed to fix a gas fire, or in fact any gas consuming appliance (such as a bath-heater) which burns more than 5 feet of gas per hour, without providing a chimney-flue to carry off the products of combustion to the outer air. These products being invisible, are supposed either to be non-existent or harmless by uneducated men.

Ventilating grates may be combined with open fireplaces. The usual method is to construct a chamber lined with fire-clay at the back and sides of the fireplace, and extending up behind the chimney-flue. An opening below admits fresh air from outside the house into the chamber; here it is warmed, and escapes by an opening into the room above the chimney piece, where it mixes with the current of air, at this spot flowing up towards the ceiling. Galton's Grate, and the Manchester School Grate act upon this principle.

Conduction and Convection.

In conduction heat passes from one molecule of air to another in contact with it. As air is a very bad conductor of heat, the process is very slow, and is altogether absorbed—as regards heating by fires and stoves—in the much more effectual convection, which is the conveyance of heat by means of the movements of masses of heated air. Air when heated expands, and becomes lighter bulk for bulk than an equal volume of colder air, so it rises upwards, its place being taken by the colder denser air.

Houses are heated by means of stoves in which coal, coke, gas, or oil is burnt, by hot-water pipes, and by steam pipes. The air coming in contact with the heated surfaces, is warmed, expands, and rises, and its place is taken by cold air to undergo a like process. In this way currents of warmed air circulate about a room, which tend to heat every part of it equally.

The great distinction between this class of stoves and open fire-places is seen to be that, whilst in the latter the heated air escapes up the chimney, in the former, the air, heated by contact with the stove, circulates through the room.

There is an immense variety of different kinds of heating stoves, but they may all be classified under *close* stoves and *ventilating* stoves. In the former kind no arrangements exist for providing fresh warmed air; whilst in the latter, fresh air from outside the house is made to circulate through the stove, without coming into contact with the products of combustion, and is, when warmed, passed into the room. In all stoves economy of fuel is aimed at, by providing doors and dampers to shut off the draught and make the combustion as slow as possible; and the flues are often carried horizontally for some distance, in order that a part of the waste heat may be utilised. It is evident that the slower the combustion and the more complete the utilisation of the heat of the burning fuel in warming the room, the less does a close stove act as a ventilator; and economy of fuel and utilisation of heat are purchased at the expense of healthiness.

The ventilating stoves which introduce a supply of fresh warmed air are decidedly more healthy; but there are certain disadvantages in the use of stoves of all kinds which require consideration.

In the first place, stoves are apt to render the air of a room too dry. There is the same amount of moisture in a cubic foot of the heated air as in the cold air before it is warmed: but the relative humidity of the heated air is greatly diminished, as hot air is capable of holding more moisture, before saturation is reached, than cold air; and it is upon relative humidity that health and comfort depend. This defect may to a certain extent be overcome by placing vessels of water in the room or on the stove.

Secondly, if the stove becomes overheated—if the surface temperature rises above 140° or 150° F.—the organic matters in the air become charred by contact with the heated surface, and a disagreeable close smell is perceived.

Lastly the presence of carbonic oxide—a most poisonous gas—has been detected in the air of stove-heated rooms, more especially when the stove is of cast-iron. Either this gas passes out of the furnace through invisible fissures in the cast-iron plates and joints; or it traverses the walls of the stove at a red heat. Others suppose that the gas may be formed by incomplete combustion of particles of carbon or organic matter floating in the air, when brought into contact with the hot metal.

Cast-iron stoves are very liable to become over-heated, as being good conductors they rapidly heat and cool. In such stoves, therefore, the heating surface should be increased by vertical flanges projecting from the top and sides; by which means the heat being conveyed to a larger surface is less intense, because cooling is more rapid. Care also is required in adding fresh fuel. It is safer not to use cast-iron stoves at all, unless lined inside with fire-clay which being a good non-conductor prevents the over rapid heating of the iron walls, and the warming of the room is altogether more equable. There are many stoves now made entirely of fire-clay and china, with arrangements for the supply of warmed fresh air at an agreeable temperature of about 70° or 75°. They are especially valuable for heating halls and public buildings.

Steam-pipes are largely used for heating factories and workshops where steam-power and waste steam are at hand.

Two kinds of hot-water pipes for heating purposes are in use. In the low pressure system, 4-inch cast-iron pipes are connected with a boiler so as to provide a complete circulation. The water is heated in the boiler, circulates through the pipes, parting with some of its heat to the air in contact with them, and returns again to the boiler. From the highest part of the system, a small escape pipe, to give vent to steam and hot air, must be carried into the outer air. The water circulating in such a system never acquires a temperature exceeding 200° F. or thereabouts.

In the high pressure system (Perkins') the pipes are of welded iron with thick walls and $\frac{1}{2}$ inch internal diameter. They pass through the furnace, no boiler being required. The water being under pressure can be heated to 300° or 350° F.

It is estimated that for every 1000 cubic feet of space in a dwelling house, 12 feet of low pressure piping is required to raise the temperature to 65° F., whilst 8 or 9 feet of the high pressure piping is sufficient.

Soft water is far preferable to hard water for use in boilers and hot-water pipes. The lime deposit from hard water gradually narrows the calibre of the pipes, which in time may become completely blocked. In boilers, the lime deposit forms a non-conducting lining, which prevents the passage of heat to the water, and is a frequent cause of explosion, especially in kitchen boilers. When the fur lining is thick, the iron boiler-plates become red hot from the heat of the fire; and should a crack in the fur suddenly form, the water, coming into contact with the red hot metal, is converted into steam with explosive violence. Another cause of explosion in kitchen boilers which are not connected with a hot-water cistern, or are unprovided with a steam escape pipe, is the blocking of the pipe which supplies cold water to the boiler. This occasionally happens after a hard frost, if the pipe is unprotected.

Lighting.

The daylight illumination of a room is a matter greatly affecting the comfort, if not the health of the occupants, and is of especial importance in the case of factories, workshops, and schools, where the eyesight is concentrated on small objects for many hours at a time.

The principles of illumination may be best illustrated by the requirements of a school-room in which young children are taught.

The best shape for a school-room is an oblong, with the windows in one of the longer sides only. There should be no windows on the opposite side, for cross-lights are better avoided. The area of the windows, clear of sash frames, should be not less than one-tenth, and not more than one-fourth of the floor area of the room. The windows should reach as high as the ceiling of the room and open directly into the external air.

The school desks should be arranged parallel with one another, but at right angles with the windows, and wherever possible the desks should be placed in the space intermediate between two windows. The scholars should sit with the left hand nearest the windows, so that the illumination of books and lessons may be from the left front. There is then plenty of light on the objects on the desk, but the rays are not reflected directly into the eyes of the scholars as they are in front illumination with desks facing the windows.

The defective lighting in school-rooms is one of the chief causes of short sight. The child not being able to read its book when placed at the proper distance (15 inches) from its face, stoops over the desk to lessen the distance; the eyes converge when brought too near the object, and the muscular strain thus induced causes a gradual elongation of the antero-posterior axis of the eyeball, with the production of myopia, *i.e.*, the image of the object seen forms in front of the retina, and is blurred and indistinct unless the object itself is very close to the eyes.

As subsidiary factors in the prevention of visual defects in children, the following are important. The type of school-books should be large and well-defined: For the school-books of very young children Pica type should be used, and for those of older children Small Pica—not Bourgeois or Minion. The desk should slope at an angle of 35° for writing, and 45° for reading: the height of the seat from the ground should equal the length of the scholar's leg from the sole of the foot to the knee: the depth of the seat from front to back should not be less than 8 inches: the distance of the front of the seat from a perpendicular line let fall from the edge of the desk should be not more than 1 inch, or may be 0: and the perpendicular distance of the seat from the edge of the desk should be one-sixth the height of the scholar (Newsholme). The seat should be provided with a straight back and curved pad or cushion to fit into and support the small of the back and loins. In this way the most comfortable positions may be obtained for reading and writing, and the drooping of the head from weariness which brings the eyes too close to the book is avoided. For young children the lesson hours should be broken by frequent short intervals for play, and the proper ventilation, warming, and artificial lighting of the room require careful attention.

Artificial Lighting.

The most commonly employed method of obtaining an artificial illumination is the combustion of inflammable vapours producing a flame. Coal gas, petroleum and colza oils, and candles, are well known examples of this form of illumination. In the electric light, on the other hand, there is no combustion, or only to a trifling extent; but light is emitted from a substance raised to a high temperature and a state of incandescence by the passage through it of an electric current.

The inflammable gases and vapours are chiefly compounds of carbon and hydrogen, without oxygen in coal gas and vaporised petroleum oils, marsh gas, olefiant gas, acetylene, naphthaline, &c., and combined with oxygen in colza oil.

When these inflammable vapours are heated to a sufficient temperature, the hydrogen combines with oxygen to form water-vapour, and an intensely hot flame without luminosity is produced; the carbon particles which are liberated in a state of very fine subdivision, are rendered incandescent by the heat of the hydrogen flame, and they combine with oxygen to form CO_2 and traces of CO. The luminosity which is situated in the outer portion of the flame is due to the incandescent carbon, whilst the inner portion—the hydrogen flame—is almost non-luminous. The products of combustion are chiefly water-vapour and carbonic acid. The light is very deficient in the blue and violet rays of the solar spectrum, and has therefore a yellow or orange colour. Hence the true colours of objects illuminated by a flame are not perceptible.

Coal gas.—The principal illuminant of coal gas is heavy carburetted hydrogen or olefiant gas, C_2H_4. There are also small quantities of other hydrocarbons richer in carbon, with great illuminating powers; but these are only gaseous at high temperatures, and are liable to deposit as liquids and solids in gas pipes.

Coal gas illumination was a great advance on the candle illumination of a former period, but it has certain drawbacks. There is the danger of escape of gas from mains and pipes into houses, forming, if the escape is large, explosive mixtures with the oxygen of the air; or if small, creating a serious pollution of the atmosphere. The products of combustion, the carbonic acid and sulphurous acid from the sulphur compounds in coal gas, are injurious to health, and destructive to books, furniture, and pictures indoors, and to building-stones and mortar out-of-doors. The combustion also heats the air and dries it; for although watery vapour is one of the products, the relative humidity at the higher temperature is less. Finally, unless the supply of gas and air to the flame are carefully regulated, the gas is wasted, the light is lessened, and unconsumed particles of carbon are given off which deposit as soot on the nearest cold surfaces.

The burners in common use are (1) the *fish-tail* or *union-jet*, which has a flat steatite top, slightly depressed in the centre, through which two small holes are bored in directions inclining towards one another from below up. The two streams of gas meet and produce the flat flame usually seen. (2) The *batwing* has a hemispherical steatite top, through which a vertical slit is cut for the gas to issue. The flame is flat and semicircular. The flames from these two burners require no chimneys, but are usually enclosed in globes to soften the light. (3) The *Argand* burner is a small ring or cylinder pierced at the top with fine holes for the issue of the gas. The flame is a hollow cylinder, and the air has free access both to its interior and exterior. The flame must be enclosed in a chimney.

The Argand burner has been improved by Silber, Sugg, and other manufacturers. These improvements are directed first, to cause the issue of the gas from the burner at the lowest possible velocity, and secondly to divide and regulate the air supply both to the outside and inside of the flame, and to direct a part of it to the higher portions of the flame where perfect oxidation of the carbon is most required. These improved Argands give a far better and steadier light than the flat-flame burners for the same consumption of gas.

There are several *ventilating burners* which remove the products of combustion of the flame through a flue to the external air. The *sunlight* burner used in theatres, and the *globe* light also serve to remove the heated and vitiated air from the top of the room or hall.

In the *regenerative gas burner* of Siemens, the air and gas, previous to their union, are heated in chambers surrounding the flue, by the waste heat of the combustion. The flame, which is in the form of a hollow cylinder like the Argand flame, burns around a short tube of porcelain. This tube is the commencement of the flue, and the flame, owing to the draught, turns over the top of it, and the products of combustion pass, in the flue, through the centre of the regenerative chamber, imparting their heat to the chambers containing gas and air. The flue finally opens into the external air. This form of burner is very useful where a powerful light is required as in streets, squares, halls, and public buildings. The smaller sizes do not give equally good results.

The Welsbach *incandescent gas burner* is a recent invention, which promises to have a very extended use. It consists of a Bunsen burner, with a cap (mantle) of asbestos gauze material rendered non-inflammable by chemical treatment with sulphate of Zirconium, suspended in the non-luminous flame; the flame although non-luminous is intensely hot, and the gauze mantle becomes incandescent and gives a brilliant light, far whiter than the ordinary gas flame. The flame should be enclosed in a chimney. The illuminant power is very high for gas consumed, and the heat given off is far less than with an ordinary gas flame burning the same volume. If such burners came into general use, a cheap form of gas containing no illuminants, such as water gas, could be supplied; for heat and not light are required in the flame. The cheap gas would also lead to a more general adoption of gas-heating and gas-cooking, and to the partial solution of the smoke question.

In the *albo-carbon* light, the vapour of naphthaline is burnt in the coal gas, and a brilliant white light is produced. The naphthaline, which is solid at ordinary temperatures, is placed in a reservoir connected with the gas burner, and this reservoir must be heated by a small gas jet or by strips of metal extending from the flame. The vapour of naphthaline must not be allowed to escape into the air, as its odour is most offensive.

One cause of waste and imperfect combustion with flat-flame burners—which are more largely used still than any of the improved forms—is the constant alteration in pressure in the gas pipes and mains. At one period of the day the pressure may be less than one inch of water, whilst at another it may be three inches or more. Consequently the flat flame, which is steadily burning under the low pressure, at the high pressure is flaring and singing: more gas is issuing from the burner than can be perfectly burnt, and unconsumed carbon is given off from the flame to pollute the air and blacken everything around.

To control these variations in pressure, gas governors or regulators are employed. In the larger form, the governor is fixed close to the meter, and controls the pressure throughout the house pipes; whilst a small form is made as a part of each individual burner. The best kinds of governor act automatically: by the action of valves an increased pressure narrows the lumen of the channel through which gas passes, and a diminished pressure widens it. Single burner governors are also found to answer very well.

Petroleum oils.—By the distillation of crude petroleum oil obtained from wells and borings, an oil suitable for burning in lamps—commonly called crystal oil or kerosene—is obtained. In the distillation, a volatile spirit, benzoline, and the heavy oils, some of which are solid from containing paraffin, are also obtained, and are separated from the lamp oil.

Lamp oil contains the hydro-carbons previously mentioned, and gives off an inflammable vapour which at a certain temperature takes fire. This temperature varies for different specimens of oil, and is called the "flashing point." By act of Parliament the flashing point of petroleum oils sold in this country, must be not less than 37·6° C. (100° F.).

Owing to improvements in lamps, and to the prohibition of the sale of highly inflammable oils, the danger of explosion is now very slight. As regards lamps, explosion may occur when, from any cause, the vapour over the oil in the reservoir is lighted by a spark, *e.g.*, when the wick is extinguished by blowing over the chimney, and is then depressed into the reservoir in a smouldering condition. But the best Duplex lamps (the Defries and other safety lamps) are now sold with extinguishers, and with an ingenious arrangement by which if the lamp is overturned, the flame is immediately extinguished.

Colza oil does not give off any inflammable vapour, but it is much dearer than kerosene, and the illuminating power is less. Colza oil lamps require more care in trimming than kerosene lamps.

The relative costs of candles, kerosene, colza, and coal gas to produce the same illuminating effect is seen from the following figures. To give a uniform light of 20 standard sperm candles for 100 hours, the candles would cost £4 5*s*. 9*d*.; colza oil burned in moderator lamps with Silber's burner, would cost 5*s*. 9*d*.; petroleum oil burned in Silber burners would cost 2*s*.; and coal gas burned in an improved Argand would cost 1*s*. 9½*d*. with gas at 3*s*. 4*d*. per 1000 cubic feet.*

Kerosene, like coal gas, gives off sulphurous acid when burnt, but colza oil does not. Candles, especially the cheaper kinds, give off much unconsumed carbon.

Electric light.—The electric light presents the following advantages over coal gas, oil, and candles. There is no consumption of oxygen, there are no products of combustion to pollute the air, and the heat produced is very slight. The light also is not yellow, but white. It precisely resembles solar light in being rich in the violet and ultra-violet rays. Plants grow, flower, and ripen fruit, when exposed to electric light, just as they do in sunlight, whilst photographs can be taken as easily by electric light as by day-light.

The electrical current can be produced by batteries, accumulators, and dynamo-machines, and is conveyed in copper wires to the spots where illumination is required.

In the arc light, which is suitable for lighting streets, squares, and large halls and buildings, the illumination is produced by the passage of the current through two carbon rods brought into close apposition. The re-

* Brudenell Carter, Article on Lighting, *Our Homes*.

sistance offered to the passage of the current across the space intervening between the points of the carbon rods, creates sufficient heat to cause the carbon points to become brilliantly incandescent. The light is extremely dazzling and is productive of injurious effects on the eyes of those who are much exposed to its influence.

The incandescent lamps are best suited for domestic use. In these the current is passed through a loop of filamentous carbon enclosed in a small glass globe exhausted of air, or filled with some gas such as nitrogen which does not support combustion. The resistance offered by the carbon to the passage of the current, raises it to a white heat.

CHAPTER V.

CLIMATE AND METEOROLOGY.

CLIMATE.

THE human body possesses marvellous powers of adaptability to the modified external conditions implied by changes of climate and season, and the transition from cold to heat, dryness to humidity, and *vice versâ*. The normal temperature of the body is sustained, and the bodily functions are properly performed under all the varying conditions of climate and season to be met with in the habitable globe.

In hot climates where the temperature of the air approaches, or even exceeds at times, the temperature of the blood, there is little call made upon the heat-producing powers of the body. Consequently metabolism is decreased; the urea of the urine and the respiratory carbonic acid are lessened in amount, less food being required; the digestive and assimilative powers are lessened; and oxygenation of the blood is diminished, because the number of respirations is decreased, and the heated air contains less oxygen in a cubic foot than cold air. At the same time great heat, although compatible with health, is enervating; for the perfection of bodily activity can only be attained when tissue changes are rapid. In hot climates the skin is extremely active, and the secretion of sweat enormously increased. This means great evaporation from the surface and cooling of the blood, with the result that the body temperature is maintained at its normal level.

Tropical climates (excluding malaria) are unhealthy for Europeans, only for the reason that defective sanitary arrangements, under conditions of great heat and moisture of air and soil, tend to produce, in an intensified degree, those pollutions of water and air by putrefying substances that are so destructive to health and life in all climates.

The effects of cold are exactly the reverse to those of heat. To maintain the temperature of the body, tissue metamorphosis must be rapid; food, and especially carbonaceous food, must be taken in large quantities; oxygenation of the blood and elimination of CO_2 are increased; the skin functions are reduced to a minimum, and but little blood reaching the surface, surface-cooling is obviated; whilst the rapid tissue changes permit of great bodily and mental activity being shown.

Great humidity of the air causes lessened evaporation from the lungs and skin. For the air being saturated, or nearly so, with moisture, has little drying power, and the water from the skin and lungs is with difficulty evaporated. The evaporation of water, by which much heat is rendered latent, is one of the chief sources of cooling of the body. Consequently, when air is hot and very moist, the humidity tends to increase the effects of the heat; the blood is with difficulty kept at its proper temperature; and all the disagreeable results of the high temperature are intensified.

When the air is very dry, and especially when it is also warm, so that its capacity for taking up moisture is very great, the evaporation from skin and lungs is very great. In chronic lung diseases such as bronchitis, emphysema, and some cases of phthisis with much congestion or bronchitis, dryness of the atmosphere causes cough and irritation, no doubt from the increased evaporation thrown on the lungs. The warm, equable, and fairly moist climates are best suited for the treatment of these complaints.

For healthy people in temperate climates, the pleasantest degree of humidity is about 75 per cent. of saturation (Relative humidity 75).

The effect of movement of air (winds) on evaporation is very great. In cold weather a chilly wind, if dry, increases the evaporation, and also lowers the temperature of the body by the impact of its cold particles, which absorb heat from the body, and then pass away to be replaced by more cold air. The skin becomes dry and chapped, and the lungs are irritated. In hot climates a dry hot wind increases the evaporation enormously.

At high altitudes the air is rarefied, and the pressure of the atmosphere is diminished. The other conditions met with in mountain climates, as contrasted with those of plains, are:—(1) greater movement of air—strong winds are very prevalent; (2) lessened humidity; (3) increased sunlight; (4) great freedom of the air from dust—mineral and organic (bacteria, fungi, and spores); (5) a large amount of ozone in the air; (6) a lowered temperature generally; but as the soil is rapidly heated by the sun, the days, in summer, may be warm, whilst the rapid radiation of heat, as soon as the sun sets, causes sudden cooling and a very low temperature at night. It is thus seen that the general characteristics of mountain climates are a cold, pure, dry, and rarefied air, often in rapid movement, with a large amount of light. The weight of oxygen in a cubic foot of air is diminished in proportion to the diminution of pressure; thus if the barometer stands at 20 inches, the 130·4 grains of oxygen, present in a cubic foot of dry air at 30 inches of mercury and 32° F., is reduced to $\frac{20}{30}$ of 130·4 = 86·9 grains only.

Although the weight of oxygen in a cubic foot of air is decreased at high altitudes, the oxygenation of the blood is increased, for the respirations are more frequent and have greater depth; and after a short period of residence the capacity of the chest is found to be increased in all its measurements, together with increased power of expansion and contraction. The action of the heart is also increased, and tissue change is stimulated by the low temperature and the dryness of the air, leading to improved digestion, assimilation, and excretion, with increased bodily activity.

These effects of residence at a high altitude, together with the freedom of the air from dust and germs, and its impregnation with ozone, have led to the treatment of cases of phthisis at mountain resorts, with often the most beneficial results. The cases most benefitted are those in an early stage without much congestion or bronchitis, which might be aggravated by the cold, dry air. It is advisable that spots should be chosen which are sheltered from cold winds; and those popular resorts, where many phthisical persons are crowded together in hotels and boarding houses, should be avoided. As much time as possible should be spent in the open air.

A mountainous district in proximity to the sea is liable to excessive rainfall. The moist currents of air blowing in from the sea are chilled by striking against the mountain chain; clouds are formed, and some of the moisture, no longer able to be held as invisible vapour, on account of the lower temperature, is deposited as rain, snow, or sleet, according to the temperature and season of the year. If the mountains are in the centre of a continent far removed from the sea, the rainfall may not be great.

The excess of moisture in the ocean currents will already have been deposited before reaching the hills; and in these situations a mountain climate, without the drawback of excessive rainfall, may be obtained suitable for the requirements of consumptives and invalids.

Increased pressure of the atmosphere produces effects very much of an opposite nature to those just considered. At a pressure between $1\frac{1}{4}$ and 2 atmospheres, the circulation of blood is slowed, the respirations are less frequent, and there is pain and ringing in the ears. It is found, however, that the system quickly accustoms itself to increased atmospheric pressure, and that men can work vigorously in diving-bells, in the compressed air-chambers necessary to lay the foundations of bridges and aqueducts under water, and in the very deepest mines.

The climate of small islands and of places on the seashore, differs from that in the interior of continents chiefly in its greater equability. The variations in temperature between day and night, and between summer and winter, are much less marked, whilst the winds blowing in from the sea bring a moist, but pure air, rich in ozone and free from dust and germs. The specific heat of water is far greater than that of the solid rocks composing the earth's crust. Hence water heats slowly, but parts with its heat slowly. The land heats quickly and radiates quickly. In winter the ocean acts as a storehouse for the heat absorbed from the summer sun, and slowly parts with it to warm the superincumbent air. In summer the land is heated by the sun more rapidly than the water, consequently the air over the land is heated and rises, and a cool breeze blows in from the sea during the day. During the night, the earth is rapidly cooled by radiation if the sky is clear; the air over the sea is then warmer than the air over the land, it rises, and a land breeze sets out to sea. On a summer's day at the seashore the air is constantly in motion, and is cool and moist; whilst in the interior it may be insufferably hot, close, and dry.

Ocean climates are of the greatest benefit to certain cases of lung disease (bronchitis, emphysema, congestive phthisis) where a pure air free from dust, but moist and of equable temperature is desired. Ocean voyages should be recommended to phthisical patients with extreme caution. The confinement and overcrowding in cabins and staterooms, the want of exercise and the costive habit thus produced, tending to excite hæmoptysis, are all grave disadvantages, and may counteract any benefit to be derived from the sea air.

The effect of vegetation on climate must not be lost sight of. In cold climates, trees and shrubs obstruct the passage of the sun's rays to the soil, which is therefore liable to be cold and moist; but in hot climates the evaporation of water from the leaves tends to dry the soil, whilst the temperature of the air is lowered, and the ground is sheltered from the direct rays of the sun and kept cool. In very dense forests the air is generally stagnant, and if there is much moist and decaying vegetation, all the conditions productive of malaria are present in a high degree. Probably in all climates a due admixture of herbage, shrubs, and trees, without dense undergrowth, but admitting the passage of free currents of air in every direction is the most conducive to health. Large tracts of country destitute of trees and vegetation, are, in hot climates, unbearably warm and dry, and in cold climates are exposed to every chilling wind and to every extreme of temperature according to the season of the year. In such districts, too, rainfall is often absent or very slight in amount—the attractive influence exerted by trees and vegetation generally upon water-charged clouds being wanting.

Meteorological Instruments.

Barometer.

In the standard mercurial barometer, the scale for reading the height of the column of mercury is divided into inches, tenths and half-tenths ($\frac{1}{20}$) of inches. To obtain more accurate readings than the scale alone allows, a sliding scale or vernier is attached. The vernier scale is divided into 25 equal parts, which are equal to 24 half-tenth divisions on the barometer scale. Consequently each division on the vernier is less than that on the barometer scale by $\frac{1}{500}$ (0·002) of an inch. For each division on the scale is 0·05 inch, and each division on the vernier is 0·048 inch.

To read the standard barometer, note the temperature by the attached thermometer, adjust the ivory point in the cistern so that it just touches the surface of the mercury, and read off on the barometer scale the division immediately below the top of the column of mercury. Then adjust the vernier (fig. 38) so that its lowest line is level with the top of the column of mercury, and count the number of divisions from below up until a line on the vernier exactly corresponds with one on the scale. Multiply the number of divisions on the vernier so obtained by 0·002, and add the result to the already observed height on the barometer scale. Corrections must then be made for temperature above 32° F.—for mercury like all other metals expands with a rise in

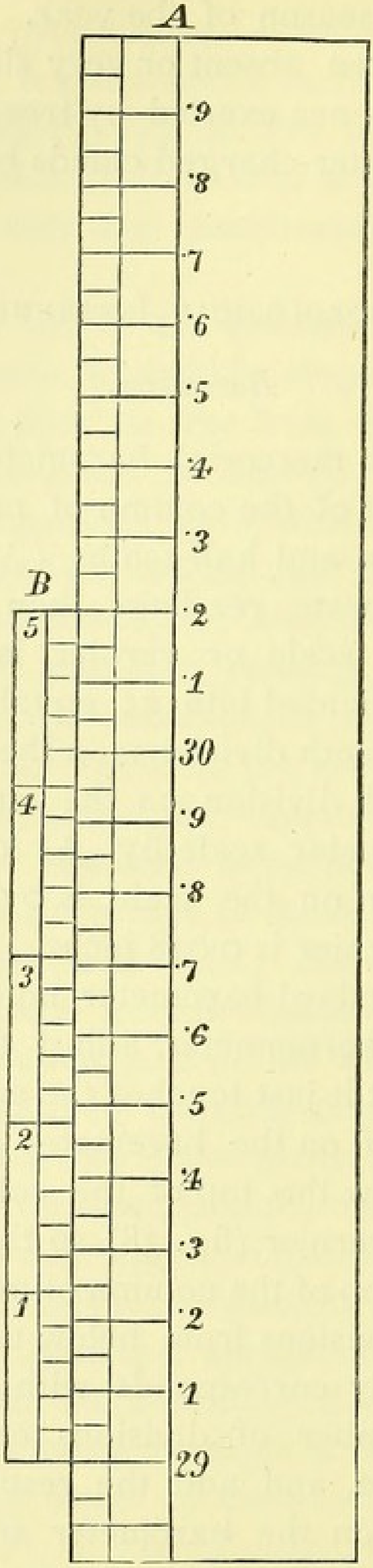

FIG. 38.—Diagram of Barometer Scale and Vernier.
A. Scale. *B*. Vernier.

temperature—and also for height above sea-level. The mercury falls about one-thousandth of an inch for every foot above sea-level.

Wet and Dry Bulb Thermometer.

The wet bulb is kept moist by being covered with muslin, one end of which dips into a small vessel of water, so that moisture ascends by capillary attraction. The evaporation of moisture from the wet bulb, which takes place so long as the surrounding air is not saturated, causes loss of heat, and the wet bulb reads lower than the dry.

From the readings of the dry and wet bulbs can be ascertained :—the *relative humidity* of the air, *i.e.*, the amount of moisture present in the air, expressed as a percentage of the amount just necessary to cause saturation; the *dew-point*, *i.e.*, the temperature at which the amount of moisture actually present in the air would cause saturation; and the weight of vapour in a cubic foot of air, from which can be deduced the additional weight of vapour necessary to cause saturation, or the *drying power* of the air.

The relative humidity is found from tables. The greater the difference between the dry and wet bulbs, the lower is the relative humidity. If the dry and wet bulbs record the same temperature, the air is completely saturated with moisture, and this temperature is also the dew-point.

The dew-point can be determined by the equation; dew-point $= T_d - (T_d - T_w) \times F$; where T_d is the dry bulb temperature, T_w the wet bulb temperature, and F the factor opposite the dry bulb temperature found in Glaisher's Tables.

The weight of vapour of water which a cubic foot of dry air can take up, until it is saturated, varies with the temperature. The higher the temperature the larger is the amount of vapour required, as the following table shows.

Grains of vapour to saturate a cubic foot of dry air (approximate),

30° F. 2 grains	66° F. 7 grains	80° F. 11 grains
41° F. 3 "	70° F. 8 "	83° F. 12 "
49° F. 4 "	74° F. 9 "	86° F. 13 "
56° F. 5 "	77° F. 10 "	88° F. 14 "
61° F. 6 "		

If the relative humidity at 61° F. is 70, the amount of vapour in a cubic foot is 70 per cent. of saturation, or $\frac{7}{10}$ of $6 = 4{\cdot}2$ grains; and the drying power of a cubic foot of the air is $6 - 4{\cdot}2 = 1{\cdot}8$ grains.

Rain Gauge.

This instrument consists of a cylindrical vessel supporting at its top a circular funnel which dips into a bottle (the rain receiver) contained in the cylinder. The gauge must be sunk in the ground a little way, and the top rim of the funnel must be perfectly horizontal. A measuring glass, graduated according to the area of the funnel, so as to indicate the fall of rain as decimals of an inch is required. The rain gauge must be fixed in an open place away from trees, walls, and houses.

Thermometers.

The shade maximum thermometer is a mercurial instrument, and is made self-registering by a narrowing of the tube near the bulb, which breaks the column of mercury when this has begun to contract after its greatest expansion.

The shade minimum thermometer is an alcohol instrument, with an index in the alcohol, which moves with the spirit on contraction but not on expansion, and is consequently left at the lowest degree of temperature, which it serves to register.

These thermometers should be placed horizontally in the shade, 4 feet above the ground, and away from buildings or other sources of radiation.

The solar radiation thermometer is a mercurial maximum self-registering instrument, with a blackened bulb. It is placed in a glass case from which air is exhausted. This instrument is placed four feet above the ground and is directly exposed to the sun's rays.

Other instruments which may be found useful are:—a terrestrial radiation thermometer, which is merely a minimum shade thermometer placed close to the ground on grass; a sunshine recorder, a little instrument by which the rays of the sun are concentrated onto sensitive photographic paper revolved by clockwork; and a self-registering weather-cock and wind-gauge (Osler's anemometer).

The presence of *ozone*, which is believed to be oxygen in an allotropic form, with the chemical formula O_2O, may be determined by means of papers saturated with starch and iodide of potassium. The ozone liberates the iodine which turns blue with the starch. Several fallacies are likely to arise from these determinations. In the first place nitrous acid, occasionally present in the air after thunderstorms, liberates the iodine as well as ozone, and in the second place the ozone may, instead of setting free iodine, form iodozone and iodate of potassium which produce no blue colour with starch. Ozone exerts a very powerful oxidising action on organic matters. When manufactured artificially, it has a very irritating effect on the lungs and bronchi. It is usually absent from the air of towns and houses.

The weight of a cubic foot of dry air at 32° F. and 30 inches of mercury is 566·85 grains. As air expands $\frac{1}{491}$ of its volume for every degree rise Fahrenheit, the volume at 60° F. for instance, is $1 + \frac{1}{491} \times (60 - 32) = 1{\cdot}057$ cubic feet. The weight is inversely as volume, consequently if x is the weight of a cubic foot of dry air at 60° F., $\frac{x}{566{\cdot}85} = \frac{1}{1{\cdot}057}$; or $x = \frac{566{\cdot}85}{1{\cdot}057} = 536{\cdot}28$ grains.

The weight of a cubic foot of vapour at 60° F. is 5·77 grains. Therefore the added weights of a cubic foot of dry air at 60, and of a cubic foot of vapour at 60° is $536{\cdot}28 + 5{\cdot}77 = 542{\cdot}05$ grains. But dry air expands on taking up moisture, and the actual weight of a cubic foot of saturated air at 60° is 532·84 grains, or 3·44 grains less than the weight of the same volume of dry air. This fact explains the fall of the barometer, when the moisture in the air is increasing, and a fall of rain is imminent. The weight of a cubic foot of air is proportional to the height of the barometer.

The percentage of nitrogen to oxygen in the air is by volume nearly 79 to 21, but by weight it is 77 to 23. From these figures the very important determinations of the weight of oxygen in a cubic foot of air under varying conditions of temperature and humidity can be made. It is only necessary to find the weight in grains of a cubic foot of the air under the observed conditions of temperature, humidity, and barometrical pressure, and then $\frac{23}{100}$ of this weight is oxygen. It is hardly necessary to dilate on the physiological and pathological importance of a knowledge of the weight of oxygen in each cubic foot of air respired under different climatological conditions.

CHAPTER VI.

SOILS AND BUILDING SITES.

THE health of a locality is intimately connected with the nature of the soil on which the houses are built. It is generally believed that the most porous soils—the gravels and sands—are the healthiest because they are the driest, and this view is in the main correct. It will be advisable, however, to consider in some detail the conditions which affect the healthiness of the different soils, and subsequently to describe the precautions that must be taken when houses are being built, to obviate such conditions as are likely to be injurious.

The porous or permeable soils—the loose sands and gravels, the sandstones and chalks—are capable of holding considerable volumes of air or water. Even the impermeable rocks—the granites and metamorphic rocks, the dense clays and limestones—are not wholly unabsorbent, but comparatively speaking they may be looked upon as impermeable. Between these and the porous sands and gravels are all stages of gradation. The surface soils which usually lie upon the denser kinds of rocks, of which they are to a considerable extent the weathered fragments, are always more or less porous. The interstices or interspaces between the particles of the porous soils are necessarily occupied by air (ground air), or by water (ground water). The ground water is derived from the rain which falls upon the surface of the earth, part of which percolates until it reaches a stratum of rock sufficiently dense to prevent its penetrating any further. Above the level of the subterranean water the interstices of the soil are filled with air.

The depth at which water will be reached in any soil depends on a variety of circumstances—the elevation above the surrounding country, the depth of the impermeable stratum from the surface, and the ease with which the underground water flows towards its natural outlet in spring, river, or sea. In the low-lying plains and valleys, the underground water is not, as a rule, far from the surface of the earth. Its level is not constant, as we have seen in the chapter on Water (p. 21), but is always changing. After heavy rainfall the level may rise; and there is usually a periodic rise, commencing in the late autumn, and a corresponding fall in the spring, due, as explained before, to the increased percolation of the rainfall in the colder months of the year, and its cessation in the warmer.

The movements of the ground water cause corresponding movements in the ground air which lies above it. As the ground water rises it occupies the space formerly occupied by the ground air, and the latter is slowly expelled from the surface of the earth; as the ground water sinks, air is sucked in to occupy its place, to be again expelled when the water rises. There are other factors influencing the movements of the ground air which have no effect on those of the ground water. The principal of these are, alterations in barometrical pressure, sudden variations in temperature, and the action of the winds forcing air into the strata which are opposed to its path. It is thus seen that the surface layers of the earth act as a sort of lung, slowly taking air in and slowly expelling it again.

This action is no doubt greatly increased in the small surface of ground covered by a house. In winter, the heat of the building and the aspirating action of fires must tend to draw air in large volumes through the surface of the soil, unless the site is covered with an impenetrable layer of asphalte or cement concrete. The ground air is generally moist and always impure. The amount of moisture depends on the proximity of the ground water to the surface of the soil; if but a few feet from the surface, the ground is saturated with moisture; but if at great depths the moisture is not excessive. The ground near the surface of the earth in most parts of the world is damp even after the most prolonged drought, owing to capillary attraction and evaporation from the surface of the ground water, and to the alternate risings and fallings in its level.

The impurity of the ground air is due to the decomposition of the various organic matters which are washed into the soil by the rain, or which are naturally present in some soils (alluvial and marshy). These latter are usually of vegetable origin. The impurity of the ground air in virgin, or natural soils, is shown by the great diminution in oxygen and the enormous increase in carbonic acid which characterised the samples that have been examined. In the neighbourhood of houses, however, the foulness of the ground air is due to animal contaminations chiefly, and these often of the most dangerous description. Leaking cesspools, sewers, and drains allow animal filth and possibly infected excretions to pollute the water and air in the soil; graveyards and cemeteries permit the exhalations from decomposing animal bodies to exercise a similar pollution; whilst the organic effluvia arising from *made* soils—soils formed of house refuse and dry rubbish—too often seriously imperil the health of the inmates of the houses built over them.

The organic matters, whether of vegetable or animal origin, are decomposed in the soil chiefly by bacterial organisms. These organisms grow in the presence of such food material, breaking it up into simpler combinations—carbonic acid, ammonia, nitrates, and nitrites —and thus, by the processes of fermentation and putrefaction, exert a purifying action, and at the same time convert the complex organic bodies into substances best fitted to be assimilated by the growing vegetation on the surface of the soil. The presence of oxygen, warmth, and moisture are essential to the proper carrying out of these fermentative processes. Oxygen is present in the ground air, moisture is derived from the ground water, and the temperature of the soil is usually sufficient, except during prolonged frosts or in very cold climates. The nitrifying action of the bacterial organisms is an especially important one, and has been more fully alluded to in a previous chapter (p. 175). Nitrate of potassium or saltpetre is still largely obtained from the soil around habitations in tropical countries.

It is thus seen that surface soil acts as a vast natural laboratory for the purification and utilisation of effete animal and vegetable matters. Even in the purest virgin soils the ground is impure, and in the polluted soils of towns and villages it is likely to be contaminated with noxious effluvia from decomposing animal filth. Hence the importance of preventing the entrance of ground air into houses, which may be accomplished by covering the entire site over which they are built by a layer of cement concrete, asphalte, or other impermeable substance.

The draining of damp soils, so as to permanently lower the level of the subsoil water, is also a measure much needed in the interests of health, but of which the utility is not so immediately apparent as in the case of the exclusion of ground air. In the first place, it is desirable to avoid great fluctuations in the level of the ground water, and this can, to a certain extent, be accomplished by subsoil drainage, which at once carries off the water when it rises to the level at which the drains are laid. When the subsoil water rises, it forces the ground air before it and out of the soil; not only this, but it causes, when it arrives within a few feet of the surface, a dampness of the atmospheric air by evaporation, and consequently a cooling of the air. The moisture ascends by capillary attraction into the walls of houses, to be subsequently evaporated from the surfaces of the interior walls; in this evaporation, heat is absorbed from surrounding objects, and the air of a house with damp walls is not only moist but cold.

This condition of dampness and moisture in the site and air of a house is one credited by universal experience with the production of rheumatism, catarrh, neuralgia, and all affections of a bronchial and pulmonary nature, and is probably a strong predisposing factor in the production of diphtheria outbreaks. A striking example of the relation subsisting between dampness of site and such diseases of the respiratory organs as measles, whooping-cough, and pneumonia, is related by Dr. Blaxall in a report to the Local Government Board on the health of Swindon.

Swindon consists of two towns—old and new Swindon. The old town lies at an elevation of about 100 feet above the new town, and is situated on oolitic limestone and Portland sand, whilst the new town with a subsoil of Kimmeridge clay was formerly liable to floods, and is still very damp. Although the two towns lie close together and differ but little socially, the death-rates from measles, whooping cough, bronchitis, and pneumonia are always far higher in New Swindon with its damp subsoil, than in Old Swindon which is comparatively dry.

The researches of Dr. Bowditch, of Boston, U.S.A., and of Dr. Buchanan in this country (9th and 10th Reports, M.O.P.C., 1866, 1867) have conclusively shown that there is an intimate connection between moisture of soil and destructive diseases of the lungs (diseases of the lungs attended with destruction of lung tissue, usually known as phthisical, and most often tuberculous). Such diseases were shown by Dr. Buchanan to be much less fatal in certain English towns, after they had been sewered and the soil consequently drained, than they had been previous to the construction of the sewer works. Where the drying of the subsoil was considerable the deaths from phthisis were reduced by a third or even by half of what they had previously been.

Professor Pettenkofer and other continental observers have sought to establish a relation between the height of the ground water and epidemic outbreaks of typhoid fever. Pettenkofer's observations were made on the wells of Munich; and they tend to show that when the water in these wells was at its lowest level, especially after a rapid fall succeeding an unusually high level, outbreaks of the fever occurred. Munich is built on a porous sandy soil, at that time riddled with cesspools, of which the contents rapidly soaked into the surrounding soil; so that it is conceivable that after heavy rainfall liquid cesspool filth should find its way into the wells, and the outbreak of typhoid fever 2 or 3 weeks after the specific pollution of the drinking water might be coincident with a fall in the ground water to its usually low level.

In this country no invariable relation has been found to exist between the onset of typhoid fever epidemics and low level of ground water. Mr. Baldwin Latham* has indeed brought forward some statistics which show that years of low ground water are often characterised by an increased zymotic mortality and high general death-rate. He points out that these periods of unhealthiness succeed periods of low ground water, and are in fact coincident with a renewal of percolation. His observations differ therefore in the most essential point from Pettenkofer's; but they are as regards typhoid fever more in accordance with the observed incidence of the disease in this country. Typhoid fever reaches its period of maximum intensity at the end of October or beginning of November in every year, as deduced from observations extending over a long series of years; and this maximum intensity also coincides with the period of lowest ground water or with the commencement of a rise following increased percolation of rain.

In considering this subject it must not be forgotten that there are other factors such as temperature, condition of the soil as regards moisture and freedom from pollution, etc., which may have a more direct bearing on health conditions than the level of the ground water. Mr. Baldwin Latham is not generally supported in his assumption that a high level of ground water is more conducive to health than a low level, but he is no doubt right in his opinion that a permanent level is better than a fluctuating one, although he does not hold the general belief that a permanently low level is better than a permanently high level. The right view appears to be that fluctuations of level are of but little consequence in

* *Transactions of the Sanitary Institute*, 1886-87., vol. viii.

themselves, but that by favouring pollution of water in wells, and by forcing impure ground air into houses, they exercise a most considerable influence on health.

Pettenkofer has expressed similar views with regard to cholera outbreaks; but it cannot be said at present that the facts, on which these views are founded, warrant more than a recognition of the occasional occurrence of coincidence of cholera outbreaks with a low state of the ground water.

The connection between malaria and damp marshy soils is more firmly established. The presence of much vegetable *débris* in the soil, together with sufficient moisture and a warm temperature, are the usual factors determining the development of the malarial agent, and the onset of ague and intermittent fevers. In many instances, malarious districts have been rendered healthy by subsoil drainage, or by tree-planting. In hot climates, trees and vegetation abstract large quantities of water from the soil, which is evaporated from their green leaves. It has been calculated that an oak-tree evaporates 8½ times the rainfall, whilst the *Eucalyptus globulus* absorbs and evaporates 11 times the rainfall over the area it covers. The latter shrub has been extensively planted in many malarious districts, and has had considerable effect in rendering them more healthy. The soil has been dried by permanently lowering the level of the subsoil water; and the moisture factor being withdrawn, the malarial agents (organisms) are no longer provided with an environment favourable to the propagation of paroxysmal fevers. It must be remembered also that moisture favours decomposition of putrefiable material; therefore a dry soil is cleaner, and the ground air is purer, than in a damp one.

In very malarious districts it is advisable that houses should be raised above the ground on arches open to the air; or in the case of wooden houses on piles. Moist ground around the site of the house should be drained and filled in, and the surface paved or covered with grass kept closely cut. Jungle and excessive vegetation should be cleared away and burnt. Where malarious currents of air drift across from marshes, the windows of the houses should open on the opposite side to the marshy district, and walls or belts of trees should be interposed to break and disperse the drifting currents.

From the above remarks it will be seen that in the choice of a site for a house, a pure, dry, and porous soil should be chosen; if possible, in an elevated position and on a gentle slop favouring natural drainage both on the surface and in the subsoil. In cold and temperate climates sands and gravels are the healthiest, because the warmest (most absorbent of heat) and driest. Clayey soils are cold, because little absorbent of heat, and they are also damp from the retention of moisture, and therefore not so healthy as the more permeable soils. Chalk is usually dry, but being little absorbent of heat, is cold. In hot climates sands are excessively hot, unless covered with herbage, which protects from the sun's rays, and cools the air by evaporation of moisture.

In towns, *made soils*—which are often mere excavations made for the purpose of removing the virgin gravel, and subsequently filled in with all sorts of rubbish and dust-bin refuse—should be avoided. If the soil is damp, the entire site below the foundations should be drained by laying unglazed agricultural pipes in trenches filled in above with pebbly gravel. This allows free percolation of water into the pipes, through the porous material of which they are constructed and between their ends, which are laid in apposition, but not jointed. These subsoil drains should not be connected with any soil-drain, sewer, or cesspool, but should discharge if possible into a ditch or stream.

To prevent the entrance of ground air, the entire site of the house, within the external walls, should be covered with a layer of cement concrete, six inches thick, rammed solid; and the surface thus formed should be coated over with cement. In large town houses with basement floors below the street level, the cemented surface when asphalted or paved may conveniently form the finished flooring. Being free from cracks and crevices it can afford no lodgment for cock-roaches or other vermin which so frequently infest the lower storeys.

In houses without cellars, more especially where the site is not concreted over, the lower floors should be raised two feet above the surface of the ground, and this space should be well ventilated through air-bricks in the external walls.

A wall built of ordinary building bricks and mortar is very porous and capable of absorbing large quantities of water. Each brick can hold about 16 oz. of water.

To obviate damp from the ground rising in the walls, a horizontal damp-proof course of slates bedded in cement, a half-inch layer of asphalte, or slabs of perforated glazed stoneware, should be inserted in the wall slightly above the level of the ground adjoining (fig. 39). The stoneware slabs answer a double purpose: they are not only damp-proof, but the perforations afford an air passage through the wall, and ventilate the space under the flooring—a very necessary precaution to prevent dry rot in timbers and joists.

The external house walls must be separated from the ground by an "open" area extending upwards from the footings or foundation. Where space will not admit of an open area, a "dry" area should be formed (fig. 39). It is merely an area a few inches wide, to prevent the moist earth coming in contact with the wall, and is

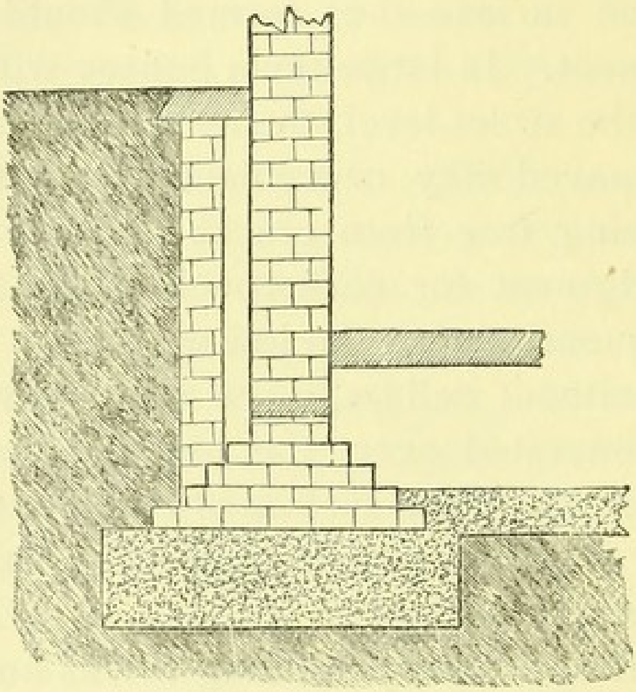

FIG. 39.—House-foundation with damp-proof course in wall and dry area.

covered at the top; or a double wall may be formed below the ground level so as to enclose a vertical air space. This arrangement necessitates two damp-proof courses; the lower just above the footings, and the upper across the outer portion of the double wall above the ground level. These arrangements are necessary to prevent damp cellars and basements.

In very exposed situations the outer walls of houses are liable to become damp from driving rain. The usual remedies are the covering of the walls with slates or glazed tiles, or coating the brickwork with Portland cement which, being impervious to moisture, is found to answer extremely well.*

* For further information on these and other points in the construction of houses the article on "Architecture" by P. G. Smith, F.R.I.B.A., and K. D. Young, F.R.I.B.A., in *Our Homes*, may be consulted.

CHAPTER VII.

FOOD, BEVERAGES, AND CONDIMENTS.

Food.

All the various food-substances, or proximate constituents of food, may be classified broadly under two heads as nitrogenous or non-nitrogenous.

The albuminates, which are substances allied in chemical constitution to albumen, form a large proportion of the nitrogenous food substances; whilst the non-nitrogenous substances consist of five well-defined classes, the fats, the carbohydrates, the vegetable acids, the mineral salts, and water.

Nitrogenous.		Non-Nitrogenous.				
		Fats.	Carbo-hydrates.	Vegetable Acids.	Salts.	Water
Albuminates. Animal	Albumen	Olein	Starch	Oxalic	Sodium chloride	
	Fibrin	Stearin	Dextrin	Tartaric	Potassium chloride	
	Syntonin	Palmitin	Cane-sugar	Citric	Potassium phosphate	
	Myosin	Margarin	Grape-sugar	Malic	Calcium phosphate	
	Globulin	Butyrin	Lactose or	Acetic	Magnesium phosphate	
	Casein		Milk-sugar	Lactic	Iron phosphate,	
	—				etc., etc.	
	Gelatine					
	Ossein					
	Chondrin					
	Keratine					
Albuminates. Vegetable	Gluten					
	Legumen					
Extractives	Kreatine					
	Kreatinine					
	Karnine					
	Xanthine					

The purposes fulfilled by food may be defined to be as follows:—1. To form new tissues in the process of growth. 2. To repair and renew the wasted tissues—solid and fluid—of the body, 3. To provide the material which serves as fuel to the body, and which by its combination with oxygen is reduced to the simpler forms of urea, carbonic acid, and water, thus supplying the sources of the animal heat and manifestations of energy which are essential for the maintenance of life.

Albuminates or Proteids.—The average composition of albumen may be taken as being somewhat as follows:—in 100 parts, nitrogen 16, carbon 54, oxygen 22, hydrogen 7, sulphur 1. The proportion of nitrogen to carbon is nearly in the ratio of 2 to 7. In the group headed by gelatine (see Table) the proportion of nitrogen to carbon is greater, and these substances are much less nutritious than the albuminates proper. In the process of digestion albuminates are converted into soluble peptones, which are highly diffusible and capable of passing through the inner coats of the alimentary tract into the blood and lymph streams.

Nitrogenous foods are essential for the maintenance of animal life. All organised structures contain nitrogen, and there can be no chemical change and no manifestation of energy in any animal tissue from which nitrogen is absent. Consequently nitrogenous foods are required for the formation of new, and the repair and renewal of old tissues, and for the formation of the digestive and other fluids of the body. The nitrogenous tissues of the body are also the regulators of the absorption and utilisation of oxygen, by which energy is manifested. Therefore, the proteid foods, which make and repair the tissues, also participate in this regulation of oxidation and energy. They are also supposed to have another function under certain special conditions, viz., the formation of fat and the yielding of energy, but of this little is known. Under a diet from which nitrogen is withheld, the body languishes; the functions are carried on at the expense of the existing tissues and structures; and these undergoing no renewal, death must eventually result.

The albuminates proper are of nearly equal nutritive value, and are therefore mutually replaceable in a diet. This applies both to the different members forming the animal albuminate class, and to the vegetable and animal albuminates taken as two separate classes. The only advantage—if indeed it be one at all—in favour of animal nitrogenous food as opposed to vegetable, is that the former is more rapidly digested, and therefore more quickly replaces wasted tissue. But against this must be set the fact, quite recently ascertained, that proteid substances become split up in the processes of healthy digestion, either in part or whole, into the poisonous alkaloids *Ptomaïnes* and *Leucomaïnes*. These bodies are, no doubt, under conditions of normal health and activity disposed of in the system without detriment to its vital functions: but if they are produced in excess, or more rapidly than they can be destroyed or eliminated, as may happen after a meal of meat excessive in amount, they tend to accumulate in the system and may be the cause of that heaviness and languor so frequently experienced by large meat eaters, especially those of a dyspeptic habit.

Whilst there is no sufficient evidence to prove that vegetarianism, so-called, is more conducive to health or longevity than a mixed diet, there can be but little doubt that the wealthier classes eat too largely and too frequently of meat. Excess of nitrogenous food causes not only an abnormal production of the poisonous alkaloids, of whose potentialities for evil but little is at present known; but an excess of nitrogenous waste accumulates in the blood, oxidation is interfered with, the liver, the kidneys, and the other excretory organs are over-taxed in their work of eliminating waste substances which are also insufficiently elaborated, and gout, liver, and kidney disease result.

Gelatine, ossein, etc., are not the nutritive equals of the other albuminates, and cannot replace them. Gelatine is easily oxidised in the body, and appears to be of value in cases of acute disease, when given in the form of jellies, in preventing excessive tissue waste. In such cases the albuminates, if given, may not be digested or assimilated. Gelatine cannot, probably, form nitrogenous tissues; but it can take the place of part of the nitrogenous substances in the blood which undergo oxidation.

The extractives, such as those contained in the juice of flesh, appear to act as regulators and stimulants of digestion and assimilation, especially when gelatine and allied bodies are comprised in the diet. Hence the use of beef-tea, which contains little beyond extractives, in the dietary of sickness.

Hydro-carbons or Fats.—These bodies are compounds of glycerine with the fatty acids, oleic, stearic, palmitic acid, etc. They contain no nitrogen, but are made up of carbon, hydrogen, and oxygen; the proportion of oxygen being less than sufficient to convert all the hydrogen into water. The fats are unacted upon by the saliva and by the gastric juice, and pass through the stomach unchanged; but in the small intestine they are emulsified by the pancreatic juice and bile, and rendered capable of absorption by the lacteal vessels, whilst a small portion is saponified, *i.e.*, split up into glycerine and fatty acids, the latter uniting with alkalies to form alkaline palmitates, oleates, and stearates (soaps), which are directly absorbed into the blood or lacteals.

The chief function of the fatty foods is to repair and renew the fatty tissues, and to yield energy and keep up the animal heat by oxidation into carbonic acid and water. The presence of the fats in food promotes the flow of the pancreatic juice and bile ; they thus help in the proper assimilation of other foods, and assist the excretory functions of the intestine, which are badly performed if bile and the other digestive fluids are not secreted in sufficient quantity.

The animal fats are more easily digested and absorbed than the vegetable. If there is excess of fat in a diet, it passes out unchanged in the fæces.

Carbo-hydrates.—These substances are made up of carbon, hydrogen, and oxygen; the oxygen being present in the exact proportion necessary to convert all the hydrogen into water. In the process of digestion, starch, cane-sugar, dextrin, and milk-sugar are converted into grape-sugar. This change is commenced in the mouth, during the process of mastication of the food, by the action of the saliva; it is not carried any further in the stomach, but is completed in the small intestine by means of the pancreatic juice. The starch ($C_6H_{10}O_5$) takes up an atom of water to become grape-sugar ($C_6H_{12}O_6$), which is taken up by the blood and carried by the portal vein to the liver, where it is deposited as glycogen or liver-starch. The liver acts as a storehouse for the deposition and accumulation of these converted starchy foods, which are subsequently supplied to the system as the needs of the economy demand, there to undergo oxidation for the manifestation of heat and energy, and for building up the fatty tissues and structures of the body.

The functions of the starchy foods are thus seen to be the production of animal heat and energy by oxidation, and the formation of new fatty tissues. The latter property has been demonstrated by Lawes and Gilbert by experiments in the fattening of pigs. The fat given in the food was not sufficient to account for all the fat stored up in the pigs. Most of it must have been derived from conversion of carbo-hydrates; but a portion may have been due to the metabolism of nitrogenous substances.

The fattening caused by a diet rich in starch and sugar, may partially be due to the oxidation of these substances saving the fatty tissues from destruction, and allowing the fat in the diet to form new fatty tissues.

Although the functions of the fats and carbo-hydrates in the economy are very much the same, they are not mutually replaceable under ordinary conditions, if health and vigour are to be maintained at their maximum. Where men are much exposed to very cold temperatures and undergo great fatigue in the open air—as during arctic expeditions—a diet of albuminates, fats, salts, and water (without carbo-hydrates), may maintain them for a time in good health. But the deprivation of fat from the diet under any circumstances is not well borne, and leads rapidly to loss of health and vigour.

It also appears that the carbo-hydrates are concerned with the maintenance of the proper reactions of the various bodily fluids (blood, lymph, gastric juice, urine, etc.). They give rise to lactic and other similar acids in the body, which act upon the alkaline phosphates, chlorides, etc., and elaborate the various acid juices characteristic of the different bodily secretions and excretions. Starches and sugars have much the same dietetic value. Cellulose is unchanged by the human digestive processes, and passes out as such in the fæces.

It is evident therefore that a diet which is to maintain proper bodily health, must contain all the three substances, albuminates, fats, and carbo-hydrates. The albuminates are the most indispensable, as without them vital action must cease for want of a supply of nitrogen. But a diet of albuminates, salts, and water, alone, is rapidly destructive of healthy action. As before explained, the excessive waste resulting from the metabolism of so much nitrogenous food, necessary to maintain animal heat and energy, overtaxes the system, and imperfectly oxidised substances accumulate in it, which pervert healthy action and eventually set up diseased processes.

Vegetable acids.—Except acetic and lactic acids, the vegetable acids contain more than sufficient oxygen to convert all the hydrogen into water. They exist in fresh vegetables and fruit, probably also in fresh meat and milk, in combination chiefly with alkalies as alkaline salts. These salts form carbonates in the system, and preserve the alkalinity of the blood and other fluids. This is their chief function, but they may also furnish a small amount of energy and animal heat by oxidation. If these substances are absent in a diet, the blood becomes impoverished and scurvy results.

Scurvy, although formerly very fatal to crews of ships on long voyages, and to populations on shore during times of want and famine, can hardly be called now a disease of modern life, when fresh meat, vegetables, and fruit are within the reach of all classes. Such is the case at least with adults; but infants, fed exclusively upon condensed milk or preserved foods, have lately been shown to suffer from a form of scurvy. The hæmorrhages characteristic of scurvy take place under the periosteum of the long bones. The disease is often associated with rickets, and is generally rapidly cured by the administration of fresh milk and fresh food.

The *mineral salts* are essential for the growth and repair of all the tissues of the body. The phosphates of lime, potash, and magnesia contribute largely to the formation of bone; whilst iron for the red blood corpuscles and colouring matters, chlorine for the gastric juice, potash for the blood cells and solid tissues, and soda for the intercellular fluids, are all indispensable. Mineral salts are required in diets for all ages, but more especially for infants and children, when not only has waste to be made good, but new material for the growth of the body has to be supplied.

Water is a component part of all the so-called solid foods, and is likewise taken separately; the amount of water contained in the solid foods of an average diet being insufficient for the needs of the body. Water is necessary to make up the losses occasioned by its excretion in the breath, sweat, urine, and fæces, and to renew all the various fluids and solid organs of the body, into whose constitution water largely enters. Water also serves as a vehicle for the solution and dilution of the solid foods, whereby they are more easily digested and assimilated, and is essential for the elimination of many waste products.

Diets.

From physiological experiment and calculation from dietaries of different kinds, tables of diets, giving the amounts of the proximate constituents of food necessary for an adult under varying conditions, have been constructed. Thus there is a subsistence diet, calculated as sufficient for the internal mechanical work of the body alone; a diet for ordinary work (consumption of visible energy equivalent to 300 foot-tons per diem); and a diet for laborious work (450 to 500 foot-tons daily); all suitable for a man of average size and weight (150 lb.), (Playfair, Moleschott, Pettenkofer, Voit, and Ranke).

	SUBSISTENCE.	ORDINARY WORK.	LABORIOUS WORK.
	Oz. Av.	*Oz. Av.*	*Oz. Av.*
Albuminates . . .	2·0	4·5	6·5
Fats	0·5	3·5	4·0
Carbo-hydrates . .	12·0	14·0	17·0
Salts	0·5	1·0	1·3
Total water-free food	15·0	23·0	28·8

The above quantities represent dry food. Ordinary food contains 50 to 60 per cent. of water, so that the above quantities must be rather more than doubled if the diet is stated as so-called solid food (not water-free). About 50 to 80 ounces of water daily are in addition taken into the system in a liquid form, the quantity depending upon the amount of exertion undergone and the temperature and humidity of the air.

By the following table, which shows the percentage composition of some of the more ordinary articles of food, it is possible to calculate a diet consisting of some of these common foods. Supposing a diet of meat, bread, and butter, is required for a body of men in ordinary work.

Let x = amount of meat required in ounces.
,, y = amount of bread ,, ,,
,, z = amount of butter ,, ,,

Then $$\frac{27.5}{100}x + \frac{8}{100}y + \frac{3.3}{100}z = 4.5 \text{ (albuminates).}$$

$$\frac{15.5}{100}x + \frac{1.5}{100}y + \frac{88}{100}z = 3.5 \text{ (fats).}$$

$$\frac{49}{100}y = 14 \text{ (carbo-hydrates).}$$

and these equations, when solved, give the required amount of meat as 8 ounces, the bread as 28·6 ounces, and the butter as 2·1 ounces.

	In 100 parts.				
	Water.	Albuminates.	Fats.	Carbo-hydrates.	Salts.
Cooked meat—no loss	54	27·5	15·5	—	3
White fish	78	18	3	—	1
Bread—white or wheaten	40	8	1·5	49	1·5
Oatmeal	15	12·6	5·6	63	3
Peas (dry)	15	22	2	53	2·4
Potatoes	74	2	0·16	21	1
Butter	6	3·3	88	—	2·7
Cheese	36·8	33·5	24·3	—	5·4
Milk, sp. gr. 1030	86·8	4	3·7	4·8	0·7
Egg, with shell	73·5	13·5	11·6	—	1

The amount of nitrogen in the diet for ordinary work is 315 grains, and the amount of carbon 4790 grains.

One ounce of albumen contains 70 grains of nitrogen and 212 grains of carbon, an allowance being made for the carbon which is excreted as urea, and which may be considered to be oxidised as far as carbonic oxide only. One ounce of fat contains 336 grains of carbon, and an ounce of carbo-hydrates about 190 grains of carbon.

In the best diets the proportion of nitrogen to carbon should be about as 1 to 15.

The *energy* obtainable from the different articles of food is expressed as so many foot-tons per ounce consumed. It is the amount which would be produced theoretically, if the constituents of the food were completely oxidised to carbonic acid and water. It is evident that such theoretical expressions may have little bearing upon dietetic value, which depends so largely upon the digestibility and capability of assimilation possessed by the different food products. In the case of the albuminates also, a portion passes out incompletely oxidised in the form of urea. The figures usually given are:—

One ounce of dry albuminate yields 173 foot-tons of potential energy.

One ounce of fat yields 378 foot-tons of potential energy.

One ounce of dry carbo-hydrate yields 135 foot-tons of potential energy.

According to these figures the average daily diet for ordinary work is capable of yielding 3977·5 foot-tons, or in round numbers close upon 4000 foot-tons. A large proportion of this theoretical energy is devoted to the maintenance of the body temperature, and to the performance of the various bodily functions.

When food is taken in large excess of the requirements of the system, a considerable portion remains undigested; fermentative and putrefactive changes are set up in the undigested mass as a result of the activity of the bacterial organisms always present in the intestinal canal, fœtid gases containing sulphur and carbon are formed, and dyspepsia and diarrhœa are provoked. Some of the products of putrefaction—possibly the alkaloids already referred to, the ptomaïnes and leucomaïnes —are absorbed into the blood and cause fever, torpor, headache, and fœtid breath. Excess of fats and starches tends to produce acidity and flatulence, whilst taken habitually in excess they may cause excessive formation of fatty tissues and obesity. In all cases of over-eating, undigested muscular fibres, fat, and starch cells may be found by microscopical examination in the fæces, and occasionally albumen and sugar will be found in the urine.

Deficiency in all the constituents of a diet tends to produce loss of weight, debility, prostration, and anæmia. If carried to the point of starvation, low fever and gastric disturbances are excited, ending eventually in death. The elimination of urea is always markedly diminished. The absence of fat in a diet leads to a state of malnutrition, possibly predisposing to such diseases as phthisis, scrofula, and tubercle, especially in children and young persons. The deprivation of starches can be borne for a long time if fat is given; but little is known as to the ultimate effects of such deprivation, for wherever food can be obtained at all, the starchy constituents, so widespread and abundant in nature, are sure to be largely represented.

Meat.

Meat contains a large quantity of the nitrogenous substances, some fat, and salts, chiefly the chlorides and phosphates of potash. It is rapidly digested and easily assimilated, and hastens tissue metamorphosis. The albuminates form 22 per cent. of raw meat (beef), of which about 17 parts are digestible albumens, peptones, and extractives, the remaining 5 parts being indigestible.

Bones contain a large amount of nourishing material, viz., albuminates (gelatine) 24 per cent., fat 11 per cent., ash or mineral salts 48 per cent. A most nourishing soup can be prepared by boiling bones. Raw meat contains some substance with anti-scorbutic properties, which is probably destroyed in cooking. The men in the Eira Arctic Expedition were fed almost exclusively on raw meat, and escaped scurvy.

In inspecting meat the muscles should be found firm and elastic, of a deep red colour—not purple nor pale—and marbled with fat in well-conditioned animals. There should be no excess of moisture, no pus or fluids in the intermuscular cellular tissue, and no lividity on cutting the muscles across. The odour should be fresh and not unpleasant, without a suspicion of putridity or smell of physic. Meat which has commenced to putrefy is pale and soft, later it becomes green. If the odour of putrefaction is not apparent, a knife should be thrust into the meat up to the hilt and then held to the nose; or a little of the meat may be chopped up and soaked in warm water. The fat should be firm and of a pale yellow colour, free from hæmorrhagic points. The lungs should be examined for inflammation or abscesses, and the liver for *Distoma* or liver-fluke.

Cysticerci (fig. 40) may be seen with the naked eye in the flesh of cattle and pigs, as small rounded bodies. Their size varies from $\frac{4}{100}$ of an inch up to $\frac{1}{4}$ of an inch in diameter. They should be further examined under the microscope with a low power for the discovery of the hooklets (fig. 40). The cysticercus of the ox produces *Tænia Mediocanellata* in man, and that of the pig *Tænia Solium.*

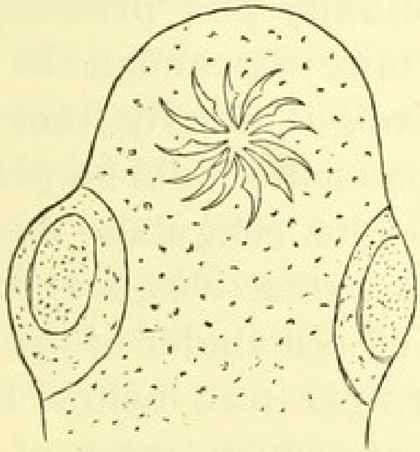

FIG. 40.—Head of Cysticercus Cellulosus × about 40 diameters.

Encapsuled *Trichinæ* may be found in pigs' flesh, especially in the diaphragm, the intercostal muscles, and the muscles of the eye and jaw. They can be seen with

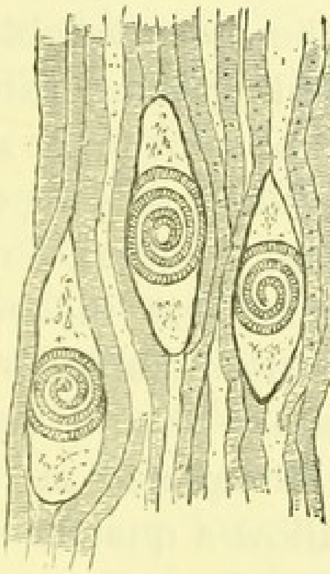

FIG. 41.—Trichina Spiralis, encysted in muscle × about 40 diameters.

the naked eye as small round specks, and should be examined under the microscope to detect the coiled up and encapsuled worm (fig. 41).

Cooking.—The *cooking* of meat is necessary, (1) to destroy any noxious organisms or poisonous bodies that may be present in raw meat; (2) to preserve it from putrefactive changes by heat sterilisation; and (3) to increase its digestibility and produce that palatability which a civilised taste demands. In all cooking processes meat loses weight, usually from 20 to 30 per cent. In *boiling* a joint, the meat should be plunged into boiling water for 5 minutes to coagulate the outside albumen and retain the salts, extractives, and soluble substances, in the interior. The remainder of the boiling should be conducted at a temperature below 170° F.—which is the temperature at which most of the albuminates coagulate—in order that the meat may not become tough, dry, and indigestible. On the other hand in making broth the meat should be cut into small pieces, and placed in cold water, which is gradually warmed to 150° F.; in this way the salts and extractive matters pass out of the meat into the broth, together with a certain proportion of the more soluble albuminates. A final heating to a boiling temperature is advisable, if there is any suspicion of taint in the stock meat, in order that putrefactive organisms may be destroyed.

In *baking* and *roasting*, the joint of meat should first be subjected to an intense heat, to coagulate the outside albumen and retain the soluble juices. After a few minutes the temperature should be lowered, and the roasting or baking completed at 180° F. to 200° F. The usual rule is to allow a quarter of an hour for every pound of meat. Aromatic products are formed in roasting and baking which are volatilised; some of the fat is melted and flows out of the joint with gelatine and extractives to form the gravy.

The gas cooking ovens, which have now come so largely into use, present several advantages over kitchen ranges heated by coal. They are very cleanly; the temperature of the oven can be regulated with great nicety by adjusting the consumption of gas; there is the convenience of the oven being ready for use in a few minutes after the gas is lighted; and as soon as the cooking is finished the gas can be turned out. It is very difficult to distinguish between a joint of meat baked in a gas oven, and one roasted before an open fire, if the gas oven is properly ventilated and a flue is provided to carry off the products of combustion. If the ventilation is insufficient either in a gas oven or ordinary close range oven, the meat becomes sodden in its own vapours, and in the case of the gas oven, also with the gas products, which give it a disagreeable taste and odour. Gas cooking stoves should be provided with Bunsen burners, arranged round the sides of the oven at the bottom; and the oven walls should be double, the space between the plates being well packed with slag wool to prevent the radiation of heat. No soot is formed in gas cooking, and there is no dust, ashes, and dirt, as in a coal cooking range.

Meat can be *preserved* by drying in strips in the sun called jerking; by salting; by canning, *i.e.*, by boiling the meat in tins, which are hermetically sealed by soldering at the boiling temperature, all germs being destroyed by the process of boiling—repeated more than once to kill the spores; and by refrigeration in the raw state—a process now very largely used, by means of refrigerating chambers on board ship, for the importation into this country of meat from South America and the Australian colonies. The last process is by far the best, as the freshness and nutritive value of the meat remain altered. It is almost impossible for any one to distinguish a New Zealand joint of mutton from the home product—if it is properly cooked. The low temperature of the ice-house (about 6° F. below freezing point), does not destroy the bacteria—the agents of putrefaction—but prevents their development so long as the temperature remains cold. The preservation, for so many ages, of the Siberian Mammoth in its icy casing is a notable example of the antiseptic properties of great cold.

Effects of diseased or unsound meat.—It may be stated as an accepted fact that thoroughly cooked meat is not likely to produce any injurious effects; even when derived from a diseased animal, or after putrefactive changes have commenced in it.* The temperature employed in boiling or baking is probably sufficient to destroy any poisonous properties such meat in a raw state may possess. Where the meat is only partially cooked, and underdone in the centre, danger may arise; and in such cases symptoms of poisoning, occasionally ending fatally, have been observed in those who have partaken of decomposing food. A large number of these instances have been connected with the consumption of sausages, pies, and hams. The symptoms are those of violent irritation of the alimentary tract, and are characterised by acute vomiting, diarrhœa and colic, increased mucous secretions, cramps in the ex-

* The most recent research, however, rather tends to show that meat which has become tainted by the presence of putrefactive bacteria, may possibly be cooked sufficiently to destroy the microbes themselves, whilst the ferments generated by the microbes, being unaffected by the cooking, continue to decompose the meat, and give rise to poisonous substances. This explains why tainted meat, eaten hot, is often harmless, but taken cold may produce symptoms of poisoning—the bacterial ferments having had time to act upon the albuminous substances of the meat.

tremities, and failure of the heart's action. Whether these symptoms are produced by putrefactive bacteria or special bacilli in the food, or by the products of their action upon albuminous substances—the poisonous alkaloids, ptomaïnes and leucomaïnes—it is impossible to say. The latter explanation appears to have some probability from the fact that these attacks are very sudden in their onset, and commence very shortly after partaking of the implicated food—pointing therefore rather to the action of a chemical poison, than of a bacterial organism requiring time for its growth and development—and that the symptoms of poisoning by the alkaloid muscarine, present very nearly identical features with those observed in these cases.

Besides a muscarine-like poison, there appears to be another poison formed in decomposing flesh and fish, which produces symptoms analogous with those of atropine, viz., quickened pulse, paralysis of the muscles of the eyeball, and diminished secretion from the mucous membranes. This poison exerts an antagonistic effect upon the muscarine-like poison; and in different cases one of these poisons may predominate over the other, and produce its characteristic symptoms more or less modified. The presence of these alkaloidal substances may possibly account for the ill effects produced by eating oysters, mussels, and some kinds of fish, such as mackerel, when out of season, and pork in hot climates.

The balance of evidence is in favour of diseased meat from cattle, sheep, and pigs being eaten with impunity, if thoroughly cooked. Sickness and diarrhœa is occasionally produced by the consumption of such food in a partially cooked condition; and certainly there can be no reason why diseased meat should be allowed to be used for human consumption, and it is very properly condemned in this country wherever exposed for sale. There are certain diseases of animals which are known to be, or believed, on good grounds, to be transmissible to man. These are anthrax or malignant pustule, phthisis and tubercle, foot and mouth disease, rabies, glanders and farcy in horses, cysticercus cellulosus in the pig and ox, and trichina spiralis in the pig. With the exception of cysticercus and trichina, all these diseases are far more frequently transmitted to man by other means, than by the consumption of diseased flesh. But it must be remembered that such transmission is possible, and would probably be much more frequent than it is, were it not for the precautions taken to prevent the sale of unsound meat, and for the safeguard of cooking.

Bovine and porcine cysticerci, which develop tænia mediocanellata and tænia solium respectively in man, are probably little affected by salting and smoking. There is good ground for believing that exposure for some minutes to a temperature above 150° F. does destroy them. The same may be said for the trichina spiralis, only the temperature must be somewhat higher, as the worm is surrounded by a dense capsule which prevents the heat reaching it.

The meat of animals which have been slaughtered in the early stages of acute inflammatory disease and epidemic pleuro-pneumonia, is probably quite wholesome, if well cooked, unless the animals have been drugged with medicines before killing. The evidence as regards the possible bad effects from the use of meat, taken from animals which have suffered from rinderpest or cattle plague, braxy or splenic apoplexy (sheep), and small-pox (sheep), is conflicting.

Milk.

Milk is the natural food of all animals belonging to the mammalia for a longer or shorter period following their birth. It therefore contains all the constituents of the standard diet, and these in the proportions most favourable for the growth and development of the young animal. In many of the milks secreted by the different kinds of animals, the fats, the nitrogenous substances, the salts and the water, are found in proportions, as compared with the carbo-hydrates, largely exceeding those contained in the ordinary food of the adult animal. This is notably the case in man; the albuminates, the fats, and the salts being required in large quantities for the rapid growth of the body in infancy, whilst the water is essential for the quick formation of tissue and for the rapid elimination of waste products.

The varying proportions of the different solid constituents of milk as secreted by the human female, the cow, the ass, the goat, and the mare, are shown in the table. The presumption is that the natural milk of one

Average Percentage Composition by Weight (Wynter Blyth).

	Human Milk.	Cows' Milk.	Asses' Milk.	Goats' Milk.	Mares' Milk.
Fat . . .	2·90	3·50	1·02	4·20	2·50
Casein . . .	2·40	3·98	1·09	3·00	2·19
Albumens, etc.	0·67	0·94	0·80	·70	0·51
Milk Sugar .	5·87	4·00	5·50	4·00	5·50
Salts . . .	0·16	0·70	0·42	0·56	0·50
Total Solids .	12·0	13·12	8·83	12·46	11·20
Water . . .	88·0	86·88	91·17	87·54	88·80

young animal is not suited for the nutrition of another animal of a different species. This is certainly true of the human infant, which thrives far better on its mother's milk, or the milk of a wet nurse, than on cows' milk—the almost universal food for hand-fed children. In cows' milk the casein is in far too large proportion as compared with human milk; the fat and salts are also in excess, whilst the milk sugar is very deficient.

In the process of digestion, milk is curdled by admixture with the acid of the gastric juice; the casein and fat separate as curd, whilst the sugar, the soluble albumens, and the salts remain dissolved in the water as whey. The curd of human milk forms a loose flocculent mass, easy of digestion and assimilation; whilst cows' milk clots in putty-like or wet cheese-like masses. The cows' milk curd is with difficulty digested; it gives rise to dyspepsia, flatulence, and diarrhœa, and much of it may be passed unaltered in the fæces. Asses' and mares' milk approximate much more closely in composition to human milk, and give a loose, flocculent, and digestible curd like human milk. Goats' milk is too rich in fat and proteids, but it also gives the proper kind of curd in the human stomach.

For hand-fed infants under 9 months of age, if cows' milk is used, it should be given diluted with water and with the addition of milk sugar. The dense clotting may be, to a certain extent, prevented by the addition of some mucilaginous substance to the milk, such as pearl barley-water well boiled and strained, which has the mechanical effect of preventing the particles of casein coming too close together, and the curd thus formed is looser and more easily attacked by the digestive juices.

Koumiss is a fermented drink prepared from mares' milk in Russia and Tartary, and in this country it is now made largely from cows' milk. It is very easily digested and absorbed, and is a valuable food for invalids.

All the solid constituents of the milk are dissolved in the water of the milk, with the exception of the fat, which exists as innumerable minute globules floating freely in the fluid.

Cows' Milk.—The average milk secretion of a healthy cow may be taken as 20 to 25 pints daily; but the quantity of milk and its richness in solid constituents depend largely upon breed in different cows, and in the same cow upon its age, the age of the calf, and the season of the year as influencing its food. As a general rule it may be stated that cows' milk should have not less than 12·5 per cent. of total solids, of which 3·2 per cent. is fat, and 0·7 per cent. is salts, the specific gravity of the milk being 1029 or 1030, and the percentage of cream by volume not less than 10 per cent.

To make up the standard diet for an adult man of 23 ounces of water-free food, 9 pints of milk (sp. gr. 1030) must be consumed. In such a diet the albuminates, the fat, and the water would be far in excess of the requirements of the system. A prolonged course of milk diet—no other food being given—has been found exceedingly useful in certain cases of albuminuria and kidney disease. Skimmed milk only should be taken, and a portion of the casein should be separated by rennet (a preparation from the gastric mucous membrane of the calf). By this means the diet is deprived of much of its fat and albuminates; and the other constituents, being very assimilable, give the kidneys little work to do in elimination, whilst the water clears away disease products from the uriniferous tubules and promotes and restores healthy function.

Many persons, from constitutional idiosyncrasy or weak digestion, cannot drink milk at all. If the milk is first curdled by the addition of a few drops of acetic acid or a little rennet, and the curds and whey, thus formed, beaten up together and a little salt and pepper added, a most digestible dish is prepared, by reason of the stomach being saved the operation of curdling which is the cause of the disagreement.

When milk is allowed to stand the cream rises to the top of the vessel in about 6 hours; a centrifugal apparatus is now largely used for the separation of cream. Subsequently milk undergoes the lactic fermentation, and becomes markedly acid, the sugar being converted into lactic acid by the agency of a special bacterium which grows and multiplies in the milk at suitable temperatures. The milk becomes curdled, and the whey separates from the curd. At a later stage the lactic acid is converted into butyric acid by means of another bacterium or bacillus; the milk at the same time becomes turbid, and putrefactive changes set in from the growth of bacterium termo and other saprophytic organisms.

Milk may be sterilised, and thus preserved from fermentation and decomposition by repeated boilings in vessels which are hermetically sealed at the boiling temperature. It is also preserved in a desiccated form as a powder, the water being expelled by evaporation; or it is mixed with sugar and highly concentrated, being then sold as "Swiss Condensed" Milk. It has lately become the custom, where milk is sent by railway from country farms to town retailers, to add a little salicylic acid, boro-glyceride, or boracic acid to the milk as a preservative against fermentative changes in transit. Whatever antiseptic is used, it is consumed with the milk by the customer, and adds another danger to the already large catalogue attributable to milk.

There is at the present time a very copious literature dealing with the diseases and injurious effects attributable to the use of cows' milk. Forming as it does, so large a proportion of the daily food of infants, young children, and invalids of all ages, and consumed, as it generally is, by all ages and all classes, in an uncooked state, the importance of the inquiries that have been made and of the facts that have been elicited can hardly be over-estimated. The following considerations will be found of use in arriving at a proper understanding of the subject.

Milk has a remarkable power of absorbing gases and vapours, organic and inorganic. It is, besides, a fluid which, while possessing all the essential constituents of food, forms a most suitable cultivating medium for low forms of life, fungoid or bacterial. So that it is not too much to assume that specific disease germs which have gained access to the milk, may so grow and multiply as greatly to increase its power of infection as time elapses.

Milk, as being derived from the living animal, must be also, to a great extent, a reflection of the animal's state of health. But we can go further than this, and say that milk is, for a certain period, derived from an animal in the puerperal condition consequent on parturition—a condition known to be liable to certain disorders, chiefly inflammatory, and particularly prone to take the infection of contagious disease.

Milk which has become acid from lactic fermentation, is liable to cause sickness and diarrhœa in children; and if *oidium albicans* is present in the milk, it may attack the mouth and digestive tract of infants causing thrush.

Other fungi and moulds—penicillium, aspergillus, mucor, etc. (see p. 75)—when present, may cause severe gastric irritation. Similar symptoms have been produced by pus and fluids from inflamed udders and udder abscesses contaminating the milk.

We thus see that cows' milk may become injurious from the fermentative changes to which it is liable after exposure to the air; from its capacity for absorbing foul gases and vapours when stored in uncleanly places; and from its ability to harbour and foster microbes and spores which may come in contact with it—all these causes operating after the milk has been drawn from the cow. Besides all this, there is now a large body of evidence to support the view that disease of the cow may be transmitted through the milk secretion to human beings.

In 1881 Mr. Ernest Hart, in a paper read before the International Medical Congress, gave tables with particulars of 50 epidemics of enteric fever, 15 of scarlet fever, and 6 of diphtheria—4800 cases of infectious disease in all—which had been traced to an infective or a supposed infective quality of the milk supplies, and since that date there have been numerous other milk epidemics recorded.

In the case of *enteric fever*, the most usual means by which milk obtains its specifically infectious quality is the washing of the milk cans or the intentional dilution of the milk with water polluted by typhoid dejecta. In other cases, the milk has been found to be stored in rooms or dairies, the air of which was subject to drain or sewer emanations, presumably containing the specific poison of the fever. It is also possible that enteric fever is a disease of cattle communicable to man through the milk secretion, or by means of pollution of the milk by the alvine discharges through careless milking. In Germany, Walder has examined calves dead of a disease bearing a very strong resemblance to enteric fever, if not actually identical; and in this country milk epidemics of typhoid have been recorded, which were associated with a diseased condition of the cows supplying the milk, and a failure to trace the origin of the outbreak to a human source. Such evidence is, however, of no great value and requires confirmation in every particular.

In those epidemics of *scarlet fever* which have been traced to milk, it has been usual to find that the milk was infected in the ordinary way by a previous case of the disease at the farm or dairy. The cows were milked by a person who was attending on a scarlet fever patient, who had the disease amongst his family—possibly in an unrecognisable form as sore throat without rash—or who was himself suffering from it in a mild or disguised form. Occasionally the milk appears to derive its infective quality from being kept in a room in which clothes or refuse matters from the sick are lying.

But besides such easily understood methods, the history of the Hendon and Wimbledon outbreaks serves to show that cows are liable to a disease identical with or very closely resembling human scarlet fever, and that the milk from animals so suffering has been the cause of epidemic outbursts of the disease amongst those who consumed it. Dr. Klein isolated an organism—a streptococcus—from the udder lesions (ulcers) on the Hendon cows, which he believes to be the true pathogenic organism. This streptococcus has also been found in the diseased organs and tissues of human scarlatinal cases.

Subcultures of this organism obtained from human scarlatinal cases, when inoculated into recently calved cows, are said to produce the characteristic ulcers on the teats, along with other manifestations of the Hendon cow disease; and calves fed on these sub-cultures obtain the same disease. This matter has been, however, and still is, the subject of much controversy. The opponents of the views of Dr. Klein, and of Mr. Power, who investigated the Hendon outbreak, hold that a possible human source of the disease at Hendon was not absolutely excluded, and assert that other cows which had the Hendon disease did not give rise to any scarlet fever outbreak. Dr. Crookshank also has sought to prove that a disease of cows in Wiltshire—which may or may not be the Hendon disease—is really cow-pox, and that inoculation with matter from the diseased cows produces the characteristic vesicles. It is desirable, therefore, to reserve judgment until the true facts are entirely set at rest.

In a large percentage of the milk epidemics of *diphtheria*, it has not been possible to trace the source from which the milk derived its infective quality. This is not to be wondered at, for, in the first place, our knowledge is not yet sufficiently definite to enable us to exclude diphtheria from the class of diseases which are not necessarily dependent on a pre-existing case, and which, possibly arising from ordinary insanitary conditions, may be said to have a *de novo* origin; and in the second place, slight cases of diphtheria are very difficult to trace, the diphtheritic character of a sore-throat not being always recognisable even to a medical attendant. There is but little evidence tending to show that diphtheria may be a cow disease transmissible to human beings. Calves have been known to suffer from a throat affection presenting post-mortem appearances very similar to those found in human diphtheria. But this disease of calves, even if were more general than it is, would not account for diphtheria appearing amongst the customers of those establishments—the large majority in or near large towns—where the calves are sent away as soon as born, and the cows come after 3 or 4 days into regular milking. The question as to whether garget or mammitis in cows is capable of producing diphtheria in the consumers of milk taken from gargety udders, may be answered in the negative.

It certainly seems, from the evidence we possess, as if diphtheria is capable of being transmitted in milk from farms or dairies which are carefully kept and in good sanitary condition, and where apparently there has been no pre-existent case of the disease. Under such circumstances it is only natural to look to the cows themselves as the cause of the disease.

Stall-fed dairy cows in towns are very susceptible to *tubercle.* Veterinary authorities have stated that at least 25 per cent. of all dairy cows kept in towns are the subjects of this malady. These animals are stalled day and night in stables often uncleanly and badly ventilated, and they are perpetually being drained of large quantities of milk. Prolonged lactation in the human female is well known to be a frequent precursor of phthisis; and it is not wonderful that under such circumstances, and with the additional factors of confinement, want of exercise, and bad air, cows should succumb to a malady to which they are in a high degree susceptible. It often happens that the best bred animals, which are also usually the best milkers, are those which are most affected. In the early stages the symptoms of the disease are ill-defined, the health of the animal is not much interfered with, and the milk secretion is as abundant as ever. Nutrition is not interfered with until the disease is far advanced, and even then the amount of milk yielded, although poor in quality, may not be diminished, and the dairy farmer continues to keep the animal in stock.

So far as at present known, the milk of tuberculous cows is free from tubercle bacilli, unless there has been —as is very frequently the case—a deposition of tubercles in the glands of the udder. In every town dairy of any size there will probably be tubercular cows, some of them most likely with tubercular udders, and as it is the common custom with dairymen to mix together the milk yielded by different cows, it is not too much to assume that tubercle bacilli may be widely distributed in the milk supply.

The bacilli of bovine tuberculosis are identical—according to all bacteriological methods at present known —with those found in tubercular formations in the human organs, although the disease presents anatomical differences in man and cattle. But these differences are probably due to differences of soil in the human and bovine tissues, the bacilli engrafting themselves in those tissues which present conditions most favourable to their growth and development.

It has been shown that the milk of tuberculous cows containing tubercle bacilli, when given as food, produces tuberculosis in rabbits, guinea pigs, and dogs. But the evidence as to the transmissibility of the bovine disease to man is at present of the slightest. This absence of evidence is due to the great difficulties surrounding such determinations, and also to the want of observation and of properly recorded data. A strong confirmation of the view that bovine tuberculosis is transmissible, at least to young children, is contained in the fact that the mortality of children under 5 years of age from primary tubercular ulceration of the intestines, and from tuberculosis of the peritoneum and mesenteric glands (tabes mesenterica) is very high. For the period 1871-80, the mortality of children under 5 from tubercular peritonitis and tabes mesenterica was at the rate of 2·5 per 1000, which approaches closely the mortality from measles (2·57 per 1000) for the same period, and is more than twelve times as great as the mortality figure from these diseases in any of the 5 year age-periods of later life. The extreme incidence of primary tubercular disease of the abdominal lymphatic system on young children is at once seen from these figures. There can be little doubt that the tubercular virus in these cases is introduced into the body with the food, and that the virus is absorbed through some part of the digestive tract. In the matter of dietary there is one great distinguishing feature between this age period and all others. Under 5 years of age, unboiled milk forms the staple food of children.

Foot and mouth disease or *epizöotic eczema* is a contagious disease, characterised by an eruption of small vesicles on the lining membrane of the mouth and the inter-digital spaces of the feet; not unfrequently the vesicles appear on the udders and teats. In the majority of cases the milk secretion is diminished as the disease progresses, and may become entirely suspended. The fever runs its course in from 8 to 15 days. The contagium exists in its most concentrated form in the lymph or serum of the vesicles (those on the teats are liable to be ruptured in milking) and in the saliva; but it also exists in the secretions, milk, and blood of diseased animals, and it possesses a long vitality and is very enduring.

Numerous outbreaks of a peculiar illness have been traced to the use of milk from cows with this disease. The symptoms were high fever, vesicular eruptions on the throat and lips, and marked swelling of the lymphatic glands of the neck. It is probable that the transmission of the disease is most certain in those cases where there are vesicles on the teats, which are sure to be ruptured in milking, the virus thus obtaining direct access to the milk.

In the case of cows suffering from *cattle plague* and *anthrax*, the milk secretion is suspended at a very early stage, whilst in *contagious pleuro-pneumonia* and *rabies* there is no evidence of any ill-effects. In *cow pox* the milk secretion is said to be rapidly diminished or suppressed.

Until cow-sheds and dairies are placed under rigorous sanitary control, and until cow diseases are better understood and recognised, the only safeguard against the spread of disease through milk is to boil it. Exposure to the heat of boiling water for 5 minutes destroys the life and action of every variety of specific disease virus, and practically sterilises the milk. The sterilisation—the destruction of all living organisms—is of especial importance where infants are fed on cow's milk. Under natural conditions, the mother's milk, as sucked in by the infant, is free from all organic life, but where cows' milk is substituted, living germs are introduced into the stomach, which may at this tender age be unable to cope with them, and loss of health and disease ensue. The act of boiling produces no alteration in the nutritive properties of the milk, and its value as a food is in no way affected thereby.

The *examination of milk* should be directed to the determination of its quality, as expressed by the amounts of its solid constituents, and to ascertain if water or other adulterants have been fraudulently added.

The reaction of the milk should be neutral or very faintly acid or alkaline. The colour should be an opaque white; a yellow colour may be due to the food of the cows, or may be imitated by the addition of annatto to the milk. There should be no peculiarity in the taste or smell.

The specific gravity varies with the temperature. The average may be taken at 1030 at 60° F. (1031 at 39° F., 1029 at 70° F.).

The cream, as measured in a cream tube, varies considerably according to the breed of the cow and its food. It should not be less than 10 per cent. by volume of the milk. If the milk has been skimmed, the cream will be low, and the specific gravity of the milk will be high; for the removal of the fat raises the specific gravity. But the addition of water lowers the specific gravity; so that a milk which has been creamed and watered may have a normal specific gravity.

To determine the total solids of the milk, a measured quantity (5 c.c.) should be weighed and evaporated to dryness over a water-bath in a platinum dish. The residue may then be weighed, and the total solids of the milk calculated. They should not be less than 12·5 per cent. by weight of the milk. The ash or mineral salts may be determined by incinerating the total solids, until all carbon is burnt off, and weighing the residue. This should not be less than 0·7 per cent. by weight of the milk. If the ash is very high, chalk, salt, or sodium carbonate may have been added.

To estimate the fat, a weighed volume of the milk (3 c.c.) should be concentrated to dryness over the water-bath after admixture with pure, clean sand. From the dried product the fat may be extracted by ether in a fat-extraction apparatus, and weighed. It should amount to not less than 3·2 per cent. by weight of the milk.

Deducting the fat from the total solids ($12{\cdot}5 - 3{\cdot}2 = 9{\cdot}3$) the solids not fat may be estimated. They should be not less than 9·3 per cent. by weight of the milk, and from this determination the amount of added water by weight —if any—can be arrived at.

If the solids not fat are 9·3 per cent. or over, no water has been added to the milk. But if less than 9·3, water has been added.

Example.—Suppose the solids not fat are only 8·5 per per cent. by weight of the milk, then

$$\frac{9{\cdot}3}{100} = \frac{8{\cdot}5}{x} \therefore x = \frac{8{\cdot}5 \times 100}{9{\cdot}3} = 91{\cdot}4; \quad 100 - 91{\cdot}4 = 8{\cdot}6$$

—the percentage of water added.

Some of the deposit from the bottom of the cream tube should be examined microscopically to detect colostrum corpuscles, pus or blood cells, starch (added to thicken a poor milk), annatto or turmeric (to colour it), and mineral particles as chalk or sand.

A large proportion of the milk retailed in London has had some of its cream separated; whilst the fraudulent addition of water is exceedingly common in districts where the adulteration acts are not enforced.

It may be added that there is no method at present known for the detection of disease poisons in milk.

Butter.

When the cream of milk is churned, *i.e.*, violently agitated in a suitable apparatus, the fat globules coalesce, entangling in their meshes some casein and serum. The butter, so formed, is then pressed to squeeze out some of the moisture, and salt added to preserve it. The percentage proportions of the constituents of butter are approximately as follows:—

Fat	83
Curd . . .	1
Ash	1
Milk-sugar .	1
Water . . .	14

The fat of butter consists of a mixture of the glycerides of the fatty acids—palmitic, stearic, and oleic—not soluble in water; and also of the glycerides of certain soluble and volatile fatty acids, principally butyric, with small quantities of caproic, caprylic, and capric acids. It is the association of about 7·8 per cent. of the triglycerides of these volatile acids with the glycerides of the insoluble acids, which gives to butter fat its peculiar and distinctive characters (Wynter Blyth).

Composition of Butter-Fat (Wynter Blyth).

Olein	42·21 =	Oleic Acid . .	40·40
Stearin and Palmitin .	50·00 =	Stearic and Palmitic acids .	47·50
		Non volatile and insoluble . .	87·90
Butyrin	4·67 =	Butyric Acid .	3·49
Caproin	3·02 =	Caproic Acid .	2·40
Caprylin and Rutin . .	0·10 =	Caprylic and Rutic acids .	0·80
	100·00	Volatile and soluble .	6·69
		Total acids	94·59

Margarine, *oleo-margarine*, or *butterine* is manufactured chiefly from beef-fat—a mixture of stearin, margarine, and olein. The beef-fat is first finely minced and heated in tanks to about 39° C. The fat melts, and the water and *débris* sink to the bottom. The melted fat is run off as a clear yellow oil, and kept at a temperature of about 30° C. The stearin solidifies at this temperature, whilst the oleo-margarine is separated as a liquid, for it solidifies at a much lower temperature than stearin. The oleo-margarine is then filtered, pressed, churned up with milk to give it the flavour of butter, coloured with annatto, and cooled with ice, when it is ready for export.

The average percentage composition of dry margarine-fat is as follows (Wynter Blyth).

Palmitin	22·3
Stearin	46·9
Olein	30·4
Butyrin, Caproin and Caprylin .	0·4

From the tables it will be seen that the obvious distinction between butter-fat and margarine-fat, lies in the fact that the butter-fat contains nearly 8 per cent. of the volatile fats, whilst the margarine-fat has barely ½ per cent. In the analysis of these fats this difference is made use of.

A weighed quantity of the melted fat (free from water) is heated in a flask with some pure caustic potash at a temperature of about 80° C., until the aromatic odour, at first perceived, is no longer noticeable. Soaps are formed by the combination of the alkali with the fatty acids, glycerine being displaced, and the volatile fats are driven off by the heat. The soaps are then decomposed in a butter flask by the action of strong sulphuric acid; the non-volatile fatty acids are liberated, and are allowed to cool and form a hard cake. The acid liquid is run off from below the cake, which is then well washed with hot water, and after again cooling, is dissolved in ether. The ethereal extract is run into a platinum dish, the ether is evaporated off, and the non-volatile fatty acids are weighed. If they amount to more than 88 per cent. by weight of the fat taken, the sample is not pure butter-fat. The percentage of foreign fat used as an adulterant can be calculated, as we know that pure butter-fat contains less than 88 per cent. of non-volatile fatty acids, whilst pure margarine-fat contains about 94 per cent. of these acids.

Cheese.

In the manufacture of cheese, casein and most of the milk fat are precipitated from milk by rennet at a suitable temperature. The curds are then pressed, to squeeze out the whey and reduce the mass to a proper shape. In the process of decay the fat increases at the expense of the casein, and numerous alkaloidal substances, extractives, and aromatic acids are produced, which give a decayed cheese its aroma. These bodies are harmless, but occasionally a poisonous ptomaïne called "tyrotoxicon" appears to be produced. This substance has also been discovered in cheap ice creams, and in milk stored during hot weather. The symptoms produced are allied to those of atropine poisoning. Various kinds of moulds grow on decaying cheeses.

Wheat Flour and Bread.

Wheat flour contains about 15 per cent. of water, 8 to 12 per cent. of gluten (vegetable albumen), and 60 to 70 per cent. of starch, sugar, and dextrin. It is very deficient in salts and fat. In the finest flour nearly all the outer envelopes of the wheat grain are separated. This separation of the bran, whilst it renders the flour fine in texture and white in colour, deprives it of much nutritious matter, for bran contains 15 per cent. of nitrogenous substances, 3·5 per cent. of fat, and 5·7 per cent. of salts. On the other hand most of this nutritious matter is in a form difficult of digestion and irritating to the bowels, for the outer envelopes of the wheat grain are hard and siliceous. Bread made from whole-meal flour is coming largely into favour. Where it can be tolerated its use may be advantageous, as it promotes evacuation of the bowels, even if it is not more nutritious than ordinary white bread. It is certainly deserving of trial by the working classes, whose diet is often deficient in salts, fat, and nitrogen, and with the modern methods of very fine grinding, its irritant properties are reduced to a minimum.

Bread is made by mixing water, yeast, and a little salt with wheat flour until a consistent dough is formed, which is allowed to rise before a hot fire, and then placed in a baking oven. By the action of the yeast at a suitable temperature, some of the starch is changed into sugar, and the sugar splits up into alcohol and carbonic acid gas. The coherent nature of the gluten prevents the escape of the carbonic acid, which forms for itself little cells in the substance of the loaf, and causes the spongy structure characteristic of well-made bread. The alcohol escapes into the air. It is important not to let the fermentative process go too far, or lactic and butyric acids may be formed, which cause the bread to be sour. Alum has the property of arresting this change, and of imparting a fine white colour to bread. Hence its frequent use by the baker.

Aerated bread is now extensively used. In this system CO_2 gas is prepared and forced through the dough under pressure. Its great advantage lies in the fact that there is no fermentation as in ordinary bread making, and no danger of sourness and acidity being produced. There is besides no loss of starch, and no yeast is left in the bread to cause fermentative changes in the stomach giving rise to acidity, heart-burn, and flatulence. On the other hand the yeast fermentation is supposed to render the bread more easily attacked by the digestive juices—in other words more digestible. Baking powders are occasionally used to disengage CO_2 gas, and cause dough to rise. They usually consist of sodium carbonate and some acid such as citric or tartaric, the acid and alkali being brought together for use.

Under the microscope (fig. 50) wheat flour is seen to consist of round or oval starch grains, of very various sizes. The smallest are mere points, whilst the larger ones may reach to $\frac{1}{1000}$ of an inch in diameter or more. Intermediate sizes are very often absent. The hilum and concentric lines of the starch grains are barely visible, if at all. Portions of the outer envelopes of the wheat grain may be detected in the coarser and more branny flours.

Wheat grains are subject to attack by certain fungi, *viz.*, (fig. 54) smut (*uredo segetum*), and bunt (*uredo fœtida*), the latter being the commonest; rust or *puccinia graminis*, which attacks the stem and leaf; and ergot (*oidium abortifaciens*), which, however, is more often a disease of rye. Amongst the numerous animal destroyers of wheat are:—*vibrio tritici* or ear-cockle, which destroy the grain and fill it with a cotton-like substance; *acarus farinæ;* and the weevil or *calandra granaria*, a little insect

—visible to the naked eye—which eats the core out of the grain leaving only the shell.

These fungi and minute animals may likewise be recognised by means of the microscope in the flour

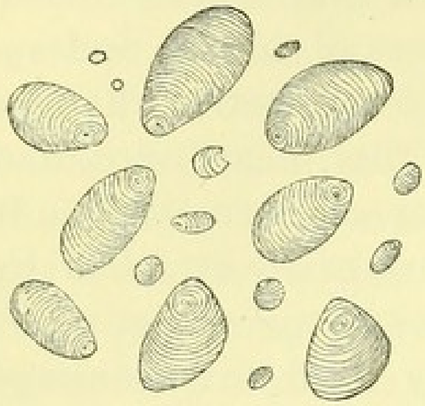

FIG. 42.—Potato × 200.

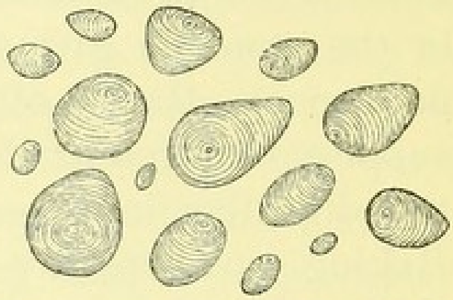

FIG. 43.—Arrowroot × 200.

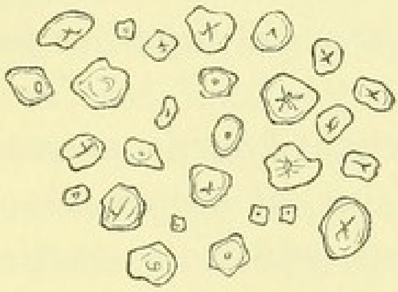

FIG. 44.—Maize × 200.

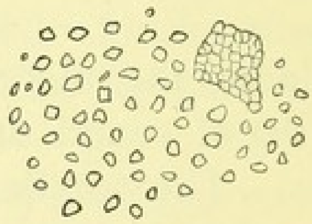

FIG. 45.—Rice × 200.

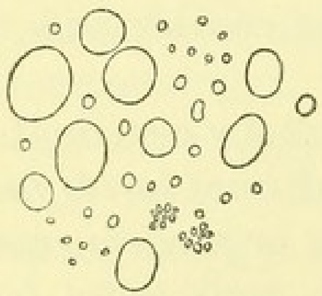

FIG. 46.—Barley × 200.

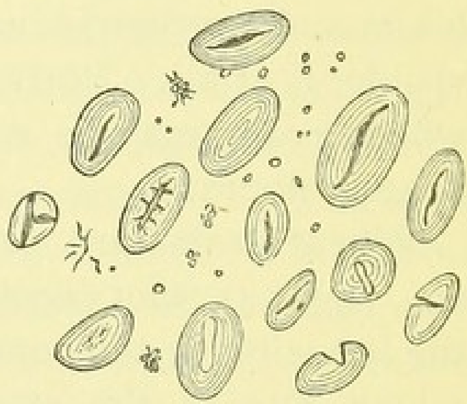

FIG. 47.—Pea × 200.

made from blighted or diseased corn; and flour and bread, when allowed to become damp or from being badly stored, become the seat of growth of moulds and fungi such as *mucor mucedo*, *penicillium*, and *aspergillus* (see p. 75). All these fungi are apt to produce dyspepsia and diarrhœa, whilst the prolonged consump-

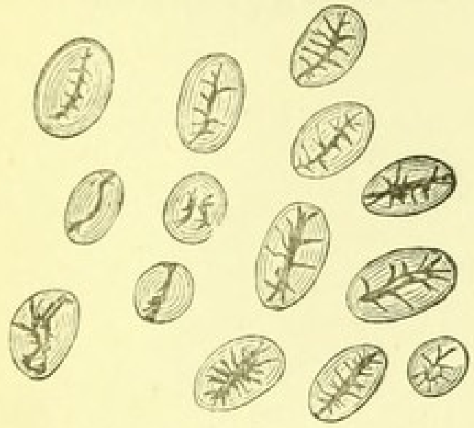

FIG. 48.—Bean × 200.

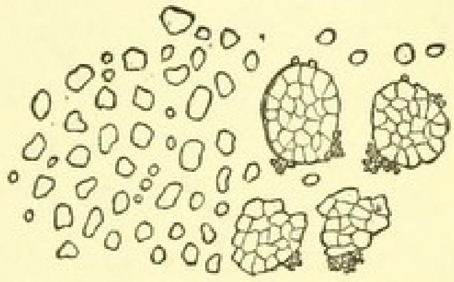

FIG. 49.—Oatmeal × 200.

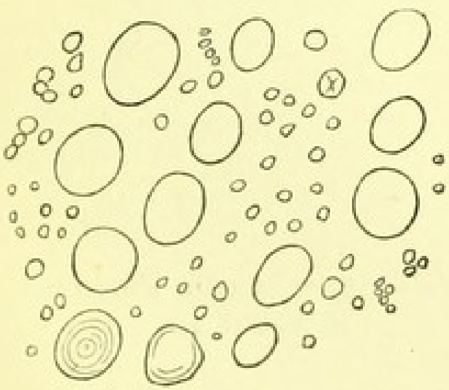

FIG. 50.—Wheat × 200.

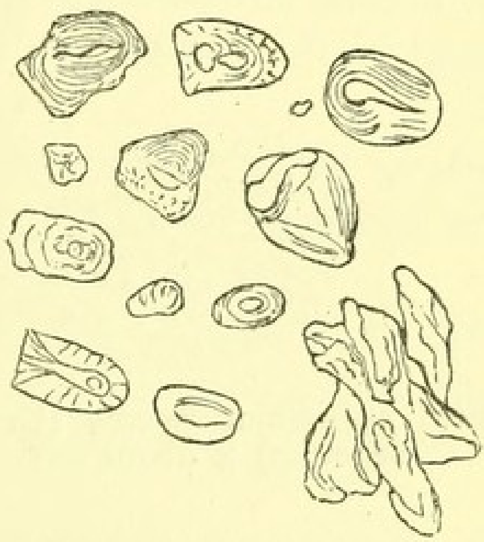

FIG. 51.—Sago × 200.

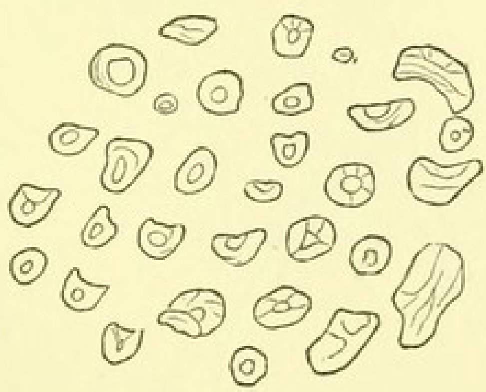

FIG. 52.—Tapioca × 200.

tion of ergoted bread may give rise to the symptoms of ergotism, *viz.*, painful cramps in the limbs, and gangrene of the extremities. Ergot may also be detected by the herring-like smell of propylamine, which is produced when liquor potassæ is added to ergoted flour.

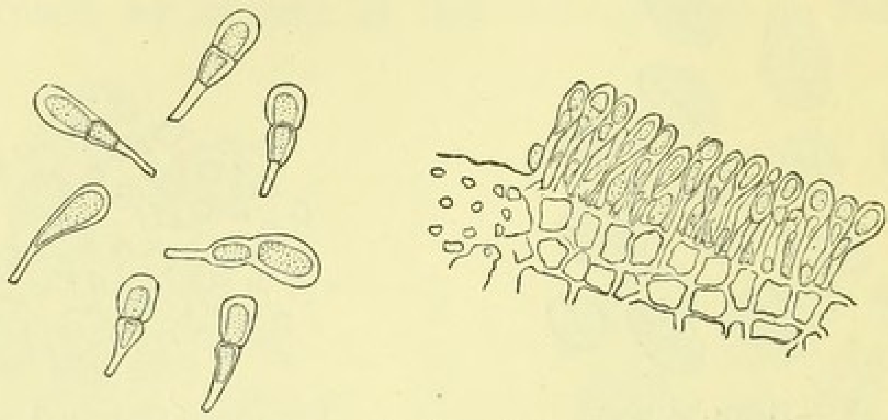

FIG. 53.—Puccinia Graminis × about 200.

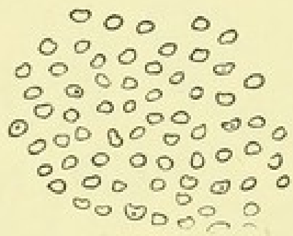

FIG. 54.—Smut Spores (Uredo segetum) × about 200

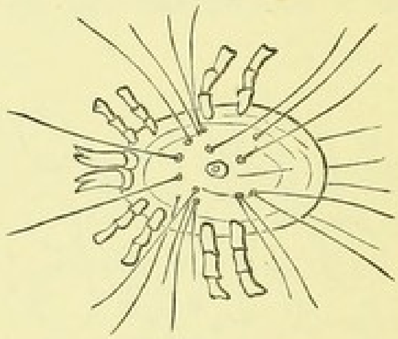

FIG. 55.—Acarus Farinæ × about 40.

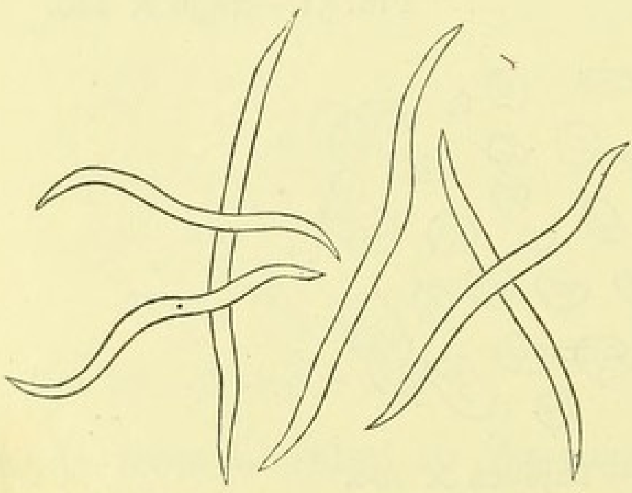

FIG. 56.—Vibriones Tritici × about 40.

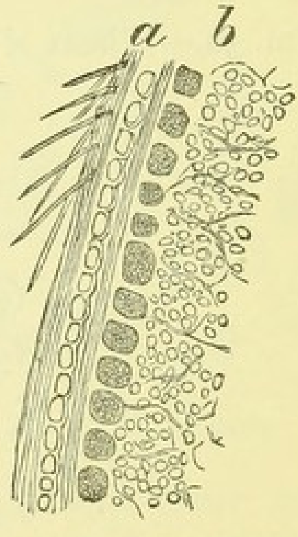

FIG. 57.—Section of Wheat Grain (outer coat) × about 100. *a.* Girdle cells. *b.* Cerealin cells.

With wheat at its present low price, adulteration is very little practised. Alum is normally present to a very slight extent in flour and bread (6 to 10 grains in a 4 lb loaf); when added in any quantity, its presence may be detected by pouring a fresh infusion of logwood, made with distilled water, over the flour or bread. The colour of the logwood changes to a bluish or violet grey, as the alum acts as a mordant.

There can be little doubt that alumed bread tends to produce dyspepsia and constipation. The alum also lessens the nutritive value of the bread, as it renders the phosphoric acid insoluble by the formation of aluminium phosphate; and it permits of an inferior flour being sold as a good one.

The adulteration of wheat flour with other grains, such as barley, potato, beans, peas, maize, oats, rye, and rice, is now but little resorted to (figs. 42-52).

The nitrogenous substances in these grains have little or no adhesive properties like wheat gluten, so that bread cannot be made from them, or only bread of inferior quality.

	In 100 parts.				
	Water.	Albuminates.	Fats.	Carbo-hydrates.	Salts.
Wheat-flour	15·0	11·0	2·0	70·3	1·7
Barley Meal	11·3	12·7	2·0	71·0	3·0
Rye	13·5	13·1	2·0	69·3	2·1
Rice	10·0	5·0	0·8	83·2	0·5
Oatmeal	15·0	12·6	5·6	63·0	3·0
Maize	13·5	10·0	6·7	64·5	1·4
Arrowroot	15·4	0·8		83·3	0·27
Peas (dry)	15·0	22·0	2·0	53·0	2·4
Potatoes	74·0	2·0	0·16	21·0	1·0
Cabbage	91·0	1·8	0·5	5·8	0·7
Sugar	3·0			96·5	0·5

The nutritive values of some of these starchy foods will be seen from the above table.* Barley-meal, oatmeal, peas, lentils, and maize or Indian corn, are all most nutritious and fattening, and very cheap. They are easily made into most nourishing porridges, soups, and puddings, with a little milk, and form very valuable —though greatly neglected—foods for people of small incomes. Starchy foods must be carefully cooked to render them digestible. By boiling or otherwise cooking, the cellulose coats of the starch granule are ruptured, and the saliva and pancreatic juice then have ready access to the granulose—the inner contents of the granule.

Barley.—The starch grains are almost indistinguishable from wheat. Barley is very nutritious, and the ash is rich in iron and phosphates.

Rye.—The starch grains are like those of wheat, but many have a peculiar rayed hilum. Rye can be made into bread, which is very acid and dark coloured, and liable to produce diarrhœa in those unaccustomed to it.

Oatmeal.—The starch grains are small and angular, and tend to cohere into rounded masses. It is most nutritious and somewhat laxative. When badly prepared, oatmeal may contain hairs and husks, which are liable to form intestinal concretions.

Maize.—The starch grains are small, compressed, and facetted. The pellagra, a wasting disease common in parts of Italy, is supposed to arise from the use of maize blighted by a fungus growth.

Peas and *Beans.*—Pea starch grains are more or less oval, and many of them have a central longitudinal cleft extending nearly the whole length of the grain. Bean starch cells are somewhat larger and more

* Parkes' *Practical Hygiene.*

flattened, and the longitudinal cleft is crossed by transverse fissures. Peas and beans contain a large amount of proteid substance called legumin (hence the name of *leguminosæ* applied to these vegetables), also sulphur and phosphorus. They are highly nutritious, but somewhat indigestible, and are apt to give rise to flatus from the formation of sulphuretted hydrogen.

Rice.—The starch grains are very minute, angular, and facetted; in shape like maize starch cells, but very much smaller. Rice is poor in everything but starch, which is, however, extremely digestible when cooked.

Arrowroot.—There are many different kinds of arrowroot obtained from various countries. As a rule the starch grains are oval or pyriform in shape, of large size, and with the hilum as a slight cleft or cross at the larger end of the grain. The concentric lines are very well marked.

Sago and *Tapioca*.—The starch grains of sago are large, irregular in shape, with ill-defined concentric lines. Those of tapioca resemble sago, but are considerably smaller.

Potato.—The starch grains of potato are very characteristic. Many of them are large and pyriform in shape, the hilum being at the smaller end, and the concentric lines are very well marked. Potatoes are very deficient in proteids and fats, but the starch is most digestible when properly cooked, and they are most valuable antiscorbutics, for they contain large quantities of the salts of the vegetable acids—malates, tartrates, and citrates. The juice of the potato is acid. Potatoes are better cooked by steaming in their skins than by boiling when peeled; for by the first method there is no loss of the salts to the water used for boiling, as occurs in the second method.

In the case of all vegetables, and in fact in all cooking processes, soft water is far better than hard water, which coats the substances with a layer of chalk deposit, and prevents the penetration of heat to the interior.

Beverages.

Coffee.

Coffee berries contain fat, legumin, sugar, dextrin, vegetable acids, and mineral salts, also an aromatic oil, an alkaloid—caffein (about 0·75 per cent.), and an astringent—coffeo-tannic acid. When the berry is roasted, it swells from the formation of gases, the sugar is changed into caramel, and the aroma is developed. The roasted coffee is made into a beverage by infusion with nearly boiling water. If the water is used at a boiling temperature, some ot the aroma is lost.

The coffee infusion acts as a stimulus to the nervous system; it increases the frequency of the heart's action, the urinary excretion, and the action of the skin, and is said to increase the evolution of carbonic acid from the lungs. It has considerable effect in removing the sensation of fatigue. It is valuable as a beverage for men undergoing exertion both in hot and cold climates, from its stimulant and invigorating qualities. The heat of the infusion is useful in cold climates, whilst the increased action of the skin produces a cooling effect in hot climates.

The principal adulterant of coffee is chicory. Occasionally starches such as wheat flour and potato flour are fraudulently added. Under the microscope, diligent search should be made for the long oval cells oi the testa of the berry with their irregular cross markings (fig. 58); and fragments of the internal structure of the berry may be seen, consisting of an irregular network of fibres forming a cellular structure, in which are contained dark angular masses and oil globules.

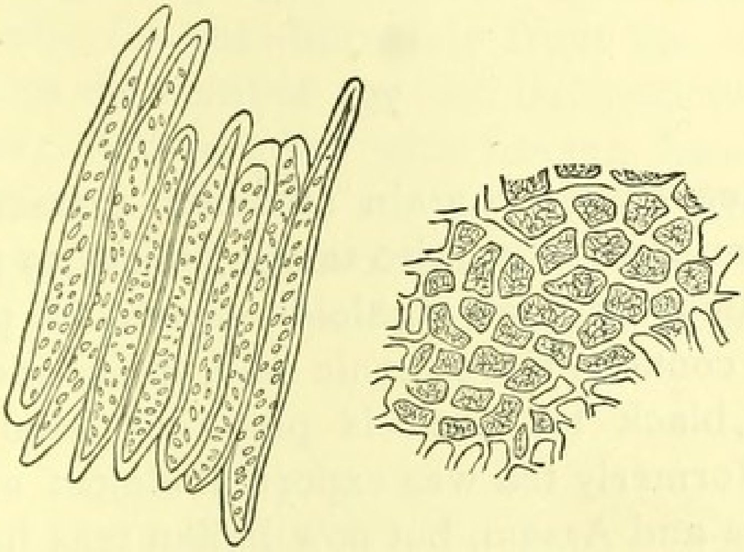

FIG. 58.—Coffee. Cells of Testa and Cellular Structure × about 200.

All these structures are better seen before the berry is roasted and ground. Chicory is revealed by the presence of fragments of much coarser areolar tissue, and by the long dotted ducts, which are quite characteristic (fig. 59).

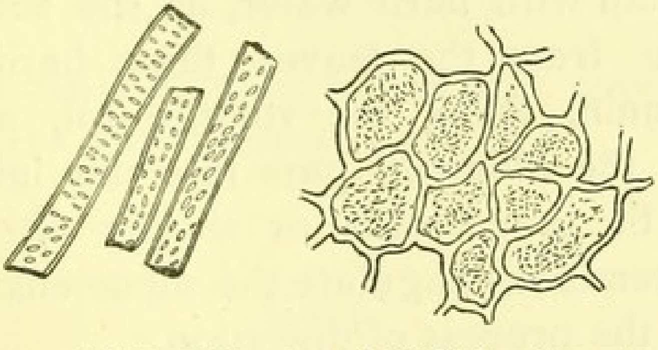

FIG. 59.—Chicory. Dotted Ducts and Cellular Structure × about 200.

Roasted coffee floats for a considerable time in water, owing to the gases that are developed in roasting, and to the quantity of oil globules; whilst roasted chicory rapidly sinks. Chicory contains no aromatic oil like coffee, but it has much sugar in its composition. When mixed with coffee it serves to sweeten it, and causes a darker coloured infusion than pure coffee gives.

Tea.

Dried tea leaves contain albumen, extractives, dextrin, and mineral salts, also tannin (about 15 per cent.), an aromatic oil, and an alkaloid—thein (1·8 per cent.). Green tea contains more tannic acid, thein, and ethereal oils than black tea, and is prepared from younger leaves. Formerly tea was exported almost exclusively from China and Assam, but now Indian teas have come largely into the market.

Tea should be made with boiling water, but it should not be allowed to stand for more than five minutes—the infusion being then poured into another vessel. If this is not done, so much tannin is extracted as to cause the infusion to be bitter and astringent, and most unwholesome. If soft water is used, a smaller quantity of tea is necessary than with hard water, as the soft water extracts more from the leaves than hard. Dextrin, glucose, tannin, thein, the volatile oil, and a small quantity of the albumen pass into the infusion. Tea should not be taken with, or shortly after meals, as the tannin tends to coagulate the albumens of the food undergoing the process of digestion.

The action of tea on the system is similar to that of coffee. It is therefore valuable as a nervous stimulant and restorative in fatigued conditions of the body. The abuse of tea leads to weakened digestion, constipation from the astringent properties of the tannin, and nervous depression leading to insomnia and trembling—the effects of the volatile oil and thein.

The structure of the tea leaf is characteristic, and is best seen when the leaf is young and green. It is oval in shape (fig. 60), with a serrated border, and the primary veins run out alternately from the midrib, and turn towards the point of the leaf, but without reaching the border. Adulteration with foreign leaves is now little practised; but used leaves may be dried, mixed with gum and rolled, and sold as sound tea. Green tea used to be coloured or faced with indigo, prussian blue,

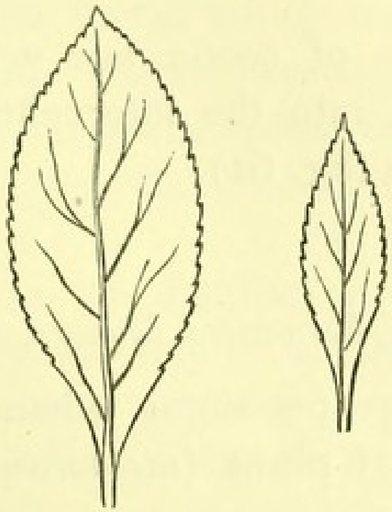

FIG. 60.—Tea Leaves (natural size).

and other mineral substances. These may be looked for in the leaves after infusion.

Cocoa.

Cocoa is a food as well as a beverage, and is much less astringent than tea or coffee. Cocoa nibs contain nearly 50 per cent. of oil, cacoa-butter), proteids about 15 per cent., and theobromin—allied to thein and caffein—1·2 to 0·5 per cent. The ash is rich in phosphate of potash. For people of weak digestion, some of the fat of the cocoa should be removed in its preparation.

Cocoa is largely adulterated with wheat and other starches, and occasionally with brick dust. Some of the homœopathic cocoas contain hardly any cocoa at all.

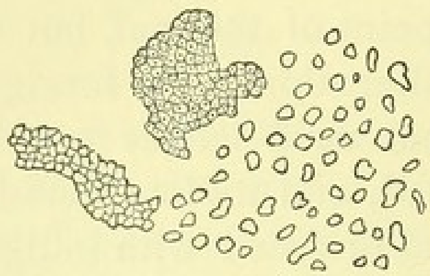

FIG. 61.—Cocoa Starch Cells × about 200.

The starch grains of cocoa are very small, and are often seen massed into the intercellular spaces of the structure of the nib (fig. 61).

Fermented Liquors.

A solution of grape sugar when subjected to the action of the yeast plant (*saccharomyces cerevisiæ*) at a

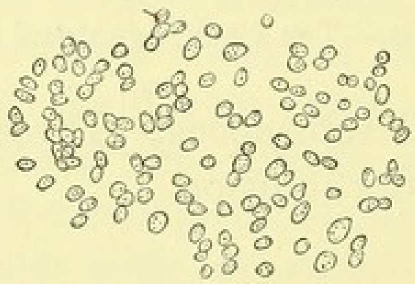

FIG. 62.—Torula Cerevisiæ (Yeast Plant) × about 200.

temperature of from 20° C. to 30° C., is mainly split up into alcohol and carbonic acid.

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

The yeast plant is composed of minute organised cells, oval in shape, and with granular protoplasm (fig. 62). In the presence of saccharine fluids at a suitable temperature, the cells undergo enormous multiplication by the process of budding, and the alcoholic fermentation ensues. Under the microscope, the cells which are budding, may be seen as one large cell united to one or two smaller cells, end to end, or groups of several budding cells are attached together. The CO_2 escapes as gas from the fermenting liquor, whilst the alcohol remains dissolved in the solution.

The fermented drinks may be considered under the heads of spirits, wines, and beers.

Spirits.—Brandy is manufactured by the distillation of wine. It contains from 50 to 60 per cent. of alcohol, the remainder of the liquid being water, in which are held various aromatic ethers (acetic, œnanthic, butyric, and valerianic) and traces of other bodies. Its specific gravity is about 0·930 at 62° F. Rum is distilled from fermented molasses.

Whisky is made by distillation of malted grain. When new, it contains amylic alcohol or fusel oil—a substance, which, when present in any quantity, produces rapid intoxication, followed by intense headache and depression. The percentage of alcohol in whisky is much the same as in brandy. Gin contains oil of juniper, and is sweetened with various aromatic substances. Absinthe is a liqueur flavoured with various essential oils, and contains oil of wormwood, a rank poison to the nervous system.

Wines.—What are known as the lighter wines—the Bordeaux, Burgundies, Rhine wines, Champagnes, and Moselles—contain usually less than 10 or 15 per cent. of alcohol by volume. The stronger wines—port, sherry, and Madeira—contain from 15 to 25 per cent. of spirit. Besides alcohol, wines contain various aromatic compound ethers (œnanthic, citric, malic, racemic, butyric, caprylic, pelargonic, etc.) which impart the bouquet, albuminous and colouring matters, sugar, free organic acids and their acid salts of the vegetable acid series, including tannic acid, which is largest in amount in new port wines, and mineral salts, chiefly those of potassium.

Wines are manufactured from the fermented juice of the grape. Cheap wines are largely made from other fruits, and even grape-juice wine is subject to various fortifications and adulterations to fit it for different markets. Home-made wines and cider are occasionally manufactured or stored in earthenware vessels, coated inside with a litharge glaze, which readily gives up large quantities of lead to acid liquids, such as these native wines are, and is thus productive of lead poisoning. If earthenware vessels are used, they should be coated with a hard salt glaze. When wine is kept long in cask or bottle, there is a deposit of the colouring matter and tannic acid, and some of the sugar disappears. If air is not absolutely excluded, the acetous fermentation is liable to be set up from the entrance of the ferment (*mycoderma aceti*), which transforms alcohol into acetic acid (C_2H_6O becomes $C_2H_4O_2$), and the wine is soured.

Beers.—In the process of brewing, malted barley is subjected to successive infusions to convert the starch into grape sugar, and this liquid—the "wort"—is then fermented, after the addition of yeast, in large open vats at a temperature of 15° C. to 18° C. The yeast floats on the surface and is removed by skimming. Hops or other bitters are then added. The percentage of alcohol in beer varies from 3 per cent. in the lighter, to 6 or 7 per cent. in the heavy beers. There are also contained in beer, malt extract (dextrin, sugar, lupulite, etc.) 4 to 15 per cent., free organic acids, traces of albuminous matters, and salts.

Considered as articles of diet, wine and beer will produce effects which may be partly ascribed to the action of alcohol on the system, and partly to the other constituents of which they are composed.

Leaving out of consideration for the moment the effects of the alcohol, it will be seen that wine and beer possess some of the properties of a food. They contain sugar and starchy matters, mineral salts, rich in potash and phosphates, and a considerable amount of the vegetable acids and acid salts which are so valuable as antiscorbutics. The compound aromatic ethers in wine may also act as aids to digestion, by promoting the flow of the pancreatic and intestinal juices; and the bitters of beer act as stomachic tonics. Little can be said against the use of beer and wine in strict moderation; but taken habitually in excess, they lead to the storage up of superfluous fat in the tissues, and they interfere with the proper elimination of effete matters; imperfect oxidation leads to an excessive formation of uric acid, and a plethoric and gouty habit are produced, eventually tending to palpable disease. These effects are, doubtless, in part due to the excess of alcohol taken into the system, but not entirely. Lessened metamorphosis has a considerable share in their production.

Effects of Alcohol.

Alcohol when taken into the body is rapidly absorbed unchanged into the blood. It speedily commences to pass out of the body in an unaltered condition. The principal channel of elimination is the lungs and breath, but small portions are got rid of by the skin, the urine, and the bowels. Some—probably the greater portion—of the alcohol is destroyed in the body. The nature of the destruction has not yet been definitely ascertained. It is evidently not oxidised into CO_2, for the pulmonary CO_2 is almost certainly lessened by the ingestion of alcohol. The transformation may be into acetic acid; and this view is rendered more likely by the fact that the acidity of the urine is slightly increased after the use of alcohol.

After full doses of alcohol given to a healthy man or animal, the following effects have been noted:—1. The vessels of the stomach are dilated, and the flow of gastric juice augmented. 2. The force and frequency of action of the heart is increased. 3. There is partial paralysis of the vaso-motor nerves on the superficial vessels, which dilate, causing flushing of the skin of the face and other parts. 4. The brain is partially anæsthetised; the rapidity of external impressions, the power of concentrated thought, and the discrimination of the senses are all lessened, as is also sustained voluntary muscular power. 5. The temperature of the body is slightly depressed; but although there may be a decreased elimination of CO_2 by the lungs, there is no delay or diminution in the metamorphosis of tissue, for the excretion of urea in the urine is not affected. 6. The acidity and water of the urine are somewhat increased.

The long continued immoderate use of alcohol leads to degenerative changes, primarily in the stomach and liver, and at a later period in the kidneys, lungs, brain, and blood-vessels. The degeneration is characterised by increased growth of interstitial fibrous tissue, which in course of time shrinks and causes atrophy of gland-cells and loss of function. Chronic catarrh and cirrhosis of the stomach with cirrhosis of the liver followed by dropsy and hæmorrhage, are the well known indications of the alcoholic tendencies of the individual.

The effect of intemperance in shortening life is now universally recognised. The statistics of temperance institutions bear overwhelming evidence on this point. It may be stated generally that the mortality of the intemperate is from 4 to 5 times greater than that of the strictly temperate of the same age and in the same class of life. The following figures taken from Dr. Ogle's report (Supplement to the 45th Annual Report of the Registrar-General) may prove of interest.

Comparative mortality of males 25-65 years of age.

	All Males (England and Wales).	Brewers.	Inn-keepers, Publicans, Spirit, Wine, Beer-Dealers.
All causes (complete mortality figure)	1000	1361	1521
Diseases of nervous system .	119	144	200
Diseases of respiratory system	182	236	217
Diseases of urinary system .	41	55	83
Liver diseases. . . .	39	96	240
Alcoholism	10	25	55
Gout	3	9	13

Those engaged in the brewing and licensed victualling trades are notably an intemperate class, but, naturally, if the temperate men in these trades could be excluded, the figures indicating special disease of organs would be very much magnified.

All evidence points to the fact that alcohol is injurious to men who are exposed to extremes of climate (great heat and great cold), or who have to undergo great bodily or mental labour. For it is in no sense a food; its oxidation—if it is oxidised—is productive neither of heat nor of energy, nor does it save any tissue destruction. Its effect on the circulation is distinctly injurious to those engaged in hard bodily work, for it causes the heart to do more work without conferring any counterbalancing advantage.

In strictly moderate doses alcohol has not been proved to do any harm; and, taken in the form of beer or wine, many of the inhabitants of our large towns find it a useful aid to digestion and assimilation. A moderate dose may be taken to be 1 to 1½ fluid ounces of pure alcohol daily. But it must be remembered that there are idiosyncrasies as regards alcohol, and that what is harmless to one individual may be injurious to another. For thoroughly healthy people, alcohol in any form presents no advantages, and for children and young people it is decidedly injurious.

Condiments.

Vinegar is prepared by acetous fermentation from white wine or malt. It shonld contain from about 3 to 5 per cent. of glacial acetic acid. It is largely adulterated with sulphuric acid, which is injurious from its tendency to form insoluble sulphate of lime in the body. Copper is an occasional adulterant. Acetic acid is neutralised in the system by soda, and ultimately becomes transformed into an alkaline carbonate.

Lemon and *Lime Juice* contain vegetable acids, chiefly citric, about 30 grains in a fluid ounce. They are most valuable antiscorbutics.

These vegetable acids and their salts are also largely contained in all kinds of fresh fruit; but perhaps the chief advantage of fruit in a diet—when taken early in the day (before breakfast)—is its tendency to promote evacuation of the bowels.

Mustard is often adulterated with wheat flour and turmeric; *pepper* with rice and sand.

Pickles are now coloured with chlorophyll and vegetable colouring matters. Formerly copper was used for this purpose.

Sweetmeats and *Confectionery* are now almost invariably sold free from any injurious colouring matter. The coloration is imparted by careful heating of the sugar, by which a variety of shades of yellow and brown may be obtained, or by the use of such harmless vegetable matters as saffron, turmeric, annatto (yellow), cochineal (red), logwood (violet), and chlorophyll (green). The use of the mineral and metallic salts for colouring purposes—those containing iron, lead, copper, arsenic, chromium, and zinc—is now hardly practised at all.

An easy and rapid test for the separation of poisonous from harmless colouring matters may be applied as follows:—Dissolve some of the sweetmeat in distilled water; if the colouring matter is soluble and is bleached on adding solution of sodium hypochlorite, it is organic and probably harmless. If the colouring matter is insoluble and is not bleached by sodium hypochlorite, it is mineral and probably poisonous.

The aniline dyes are but little used for colouring sweetmeats. They are soluble in alcohol and probably innocuous, if quite free from arsenic, which is usually the case. Picric acid (tri-nitro-phenol or carbozotic acid) a yellow dye, is, however, injurious; and the same may be said of the yellow colouring matter derived from gamboge.

CHAPTER VIII.

EXERCISE AND CLOTHING.

Exercise.

The effects of regulated exercise on the body are as follows:—

1. Increased force and frequency of the heart's action, and the free circulation of the blood through all parts of the body. 2. The pulmonary circulation being quickened, more carbonic acid and water are taken to the lungs and eliminated. The amount of air inspired and expired is largely increased, and the oxygenation of the blood is consequently accelerated. 3. The action of the skin is heightened, and perspiration becomes marked; large quantities of sweat being poured out of the sweat glands. The evaporation of the sweat from the surface of the body regulates the temperature and prevents any rise above the normal. 4. The water and salt of the urine are decreased owing to the large cutaneous secretion, but the nitrogen (in the form of urea, uric acid, and extractives) is unaffected. In the period of rest following excessive exercise, the nitrogen elimination may be slightly increased. 5. The voluntary muscles are brought into active play; the circulation of the blood through them is accelerated; waste products are rapidly carried away for excretion; whilst the material for new tissue is brought to them.

It is thus seen that exercise, which means muscular action, involves more rapid combustion as shown by the increased elimination of carbonic acid and water. Thirst and appetite are created, and water and carbonaceous foods are taken to supply the waste; whilst an increased amount of nitrogenous food, during or after periods of exercise, is necessary, first to enable the muscles to enlarge and harden, and secondly to replace the waste caused by the nitrogenous tissues performing their function of regulating oxidation.

Regular exercise in the open air is most essential to brain-workers, to purify the blood from waste matters, and to stimulate the action of the bowels.

After active exercise the body should be well washed with soap and water to remove the secretion from the sweat and sebaceous glands, which, if left on to dry, becomes mixed with shed epidermic scales from the scarf skin, and renders the skin not only dirty, but also damp, from the excess of common salt in the sweat, which absorbs moisture from the air. The damp skin causes surface cooling and often gives rise to a dangerous internal chill.

If the exercise is too severe, breathlessness and palpitation are brought on, and the pulse becomes small, very frequent, and irregular.

Prolonged exertion of a severe kind tends to cause cardiac pain and palpitation, and may give rise to hypertrophy of the left ventricle, if the over-exertion is habitual. Rupture of blood-vessels from over-exertion is uncommon before middle life. The muscles, including the cardiac muscle, require rest to get rid of the accumulated products of their action (possibly lactic acid), and to take in a fresh store of oxygen. Without definite periods of rest suited to the kind of exercise, the muscles become exhausted, and their contractions are gradually enfeebled, until they cease altogether. The diastole of the heart is quite sufficient for its recuperation when the body is at rest.

The diet of men in training should differ little, if at all, from an ordinary diet. The amount of fat and nitrogenous food may be somewhat increased out of proportion to the carbo-hydrates; but to deprive men of bread, potatoes, and vegetables, and to feed them on half-raw beef-steaks—as was formerly so largely done—is a ready means of causing the "staleness" so well known to trainers. Plenty of water, in small quantities at a time, should be allowed as the system demands. After a few days of training excessive thirst and excessive sweating disappear, and the right balance between income and outcome of fluid is quickly struck. The capacity of the chest and the elasticity of the lungs and chest walls are notably increased by regulated training, especially by training for rowing.

From numerous observations it has been deduced that an ordinary day's physical work for a healthy man is equivalent to 300 tons raised one foot (foot-tons). This is an amount of work which can be sustained day after day without loss of weight and without inconvenience. Work represented by over 400 foot-tons daily cannot be kept up unless the diet is much increased, and even then there is likely to be loss of weight and muscular vigour. It has been shown that a man walking on a level surface at the rate of 3 miles per hour does work equivalent to raising his own weight + the weight he carries through $\frac{1}{20}$ the distance walked. At this particular rate the coefficient of traction or resistance is $\frac{1}{20}$; at quicker rates of speed the coefficient more nearly approaches unity; thus at 8 miles per hour the coefficient is barely $\frac{1}{10}$.

The following formula is useful for estimating the amount of work done by a man in walking:—

Let W = weight of the man
W′ = weight he carries
D = distance walked in miles
C = coefficient of traction ($\frac{1}{20}$ at 3 miles an hour)

$$\text{Then } \frac{(W + W') \times D \times 5280}{20} = \text{foot-lb done}$$

in walking the distance D at 3 miles an hour. This number divided by 2240 (the number of lb in a ton) gives foot-tons; or generally the formula may be expressed:—

$$\frac{(W + W') \times D \times 5280}{2240} \times C = \text{foot-tons.}$$

About 16 miles at 3 miles an hour, for a man weighing 160 lb and carrying no weight, is an average days work of 300 foot-tons.

Clothing.

The ordinary garments of civilised life are made either of one, or a mixture of two or more of the following materials:—Cotton and linen from the vegetable kingdom; wool and silk from the animal kingdom.

Cotton materials have a smooth fine texture, but not equal in these respects to linen. Under the microscope cotton is seen to consist of flattened fibres with well-marked twists in their course. There are no joints or nodes and no branching fibres (fig. 63).

Cotton garments are durable, and do not shrink in washing. They are non-absorbent, and rapidly conduct away heat; hence cotton is the wrong material for under-garments, for it soaks up the perspiration and becomes wet; and the moisture is re-evaporated, causing a chill to the surface of the body. The heat of the body is not retained by cotton, but is rapidly dissipated. A novel material called "cellular" cotton-cloth has lately been introduced, which obviates the last defect. In this material the fibres are so woven as to form cellular air interspaces in the texture. Air being a good non-conductor, the cellular cloth is much warmer than ordinary cotton clothing. Cotton materials are preferable to woollen for the outer clothing of sick and hos-

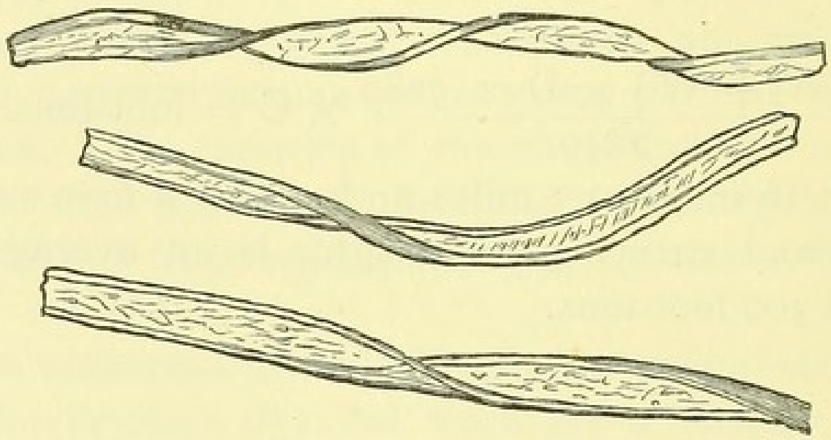

FIG. 63.—Cotton Fibres × about 200.

pital nurses, as organic matters in the air cling far less easily to cotton than to wool, and they are more readily cleaned.

Linen materials have a very fine, smooth, and close texture. Under the microscope the fibres of linen are seen to be cylindrical and jointed, with minute branching filaments at intervals (fig. 64). These latter are the elementary fibres of which the main fibre is composed. Linen is a good conductor of heat and a bad absorbent of moisture, like cotton, and is even an inferior material for under-clothing.

Wool forms a valuable material for clothing. Under the microscope the fibres (fig. 65) are seen to be rounded, colourless, unless dyed, with fine cross markings and reticulations in the border at the site of the

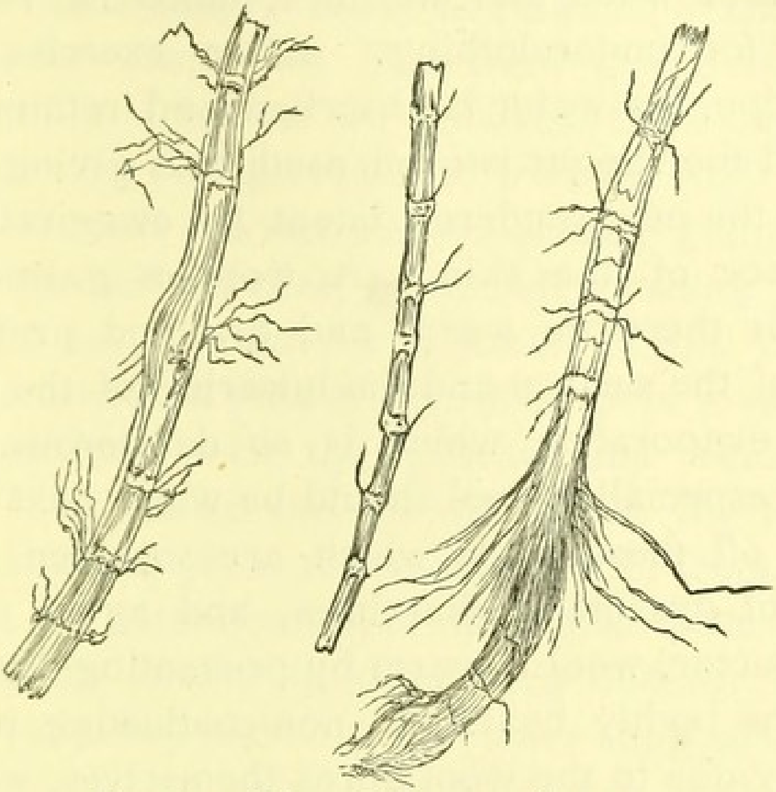

FIG. 64.—Linen Fibres × about 200.

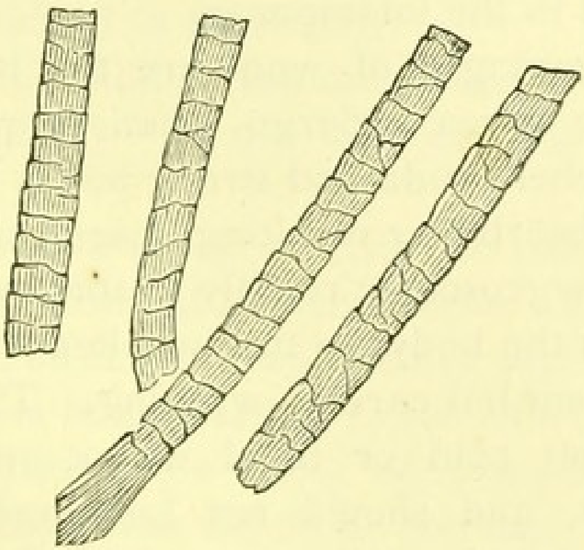

FIG. 65.—Wool Fibres × about 200.

cross markings. There is a central longitudinal canal, but it is generally obliterated. The cross markings and reticulations are best seen in new wool. When the fibres are old and worn they are not so discoverable.

Wool is a very bad conductor of heat, and is very absorbent of water and moisture, hence its value as a material for underclothing. After exercise causing perspiration, the water is absorbed and retained by the wool, and the vapour is condensed, thus giving back to the body the heat rendered latent by evaporation from the surface of the skin. A woollen garment after exercise is therefore warm and dry, and prevents the chilling of the surface and the lowering of the temperature by evaporation which is so dangerous. In hot climates especially, wool should be worn next the skin to ward off those chills which are so often the forerunners of dysentery, diarrhœa, and ague. Being a non-conductor, wool is warm by preventing the dissipation of the bodily heat. Its non-conducting properties are partly due to the wool fibres themselves, which contain an animal oil in their substance, and partly to the air entangled in the interspaces.

The disadvantages of wool are the hardening and shrinkage the fibres undergo when frequently washed (especially where soda and strong soaps are used), and the loss of absorbency resulting therefrom. The wool fibres being hygroscopic readily absorb organic vapours and dirt from the body, so that woollen under-garments require frequent but careful washing. They should be washed in soft cold or tepid water, with mild soap without soda, and should not be much wrung out. Flannel, which is a woollen material, is also often found to be too irritating to be worn next to a delicate skin.

It has lately been discovered that the addition of a little kerosene or paraffin to the soap used for washing clothes, facilitates the removal of dirt, as less rubbing and wringing of the clothes are then required; but the clothes must be well rinsed after the washing and aired out-of-doors, or a slight odour of kerosene (when kerosene soap is used) is retained in the fabrics. The paraffin soaps are free from this defect. The grease and dirt cannot be removed from clothes (no more than they can be removed from the skin owing to the fatty secretion from the sebaceous glands at the roots of the hair follicles) by merely washing in water without the use of soap. The alkali of the soap (soft soap is an oleate of potash; hard soap is a stearate of soda) combines with the grease and emulsifies it, whereby it is easily washed off, whilst the fatty acid prevents the too great removal of the oil from the wool fibres and the deterioration of the fabric. Cheap soaps, containing an excess of alkali, are bad for the skin, for it is rendered over-dry and loses suppleness by excessive removal of sebaceous secretion, and they are also injurious to woollen fabrics by carrying away the animal oil contained in the fibres.

In Merino, wool and cotton are mixed in varying proportions. "Shoddy" is old used and worked-up wool and cloth.

Silk (fig. 66) is a bad conductor of heat, but is less absorbent than wool. It presents some advantages for under-clothing, as it is more cleanly and shrinks less than wool, and is less irritating to the skin; but it cannot hold perspiration like wool. It is besides expensive, and is less durable than cotton or merino.

Leather and *Waterproof Material.*—These are invaluable for exposure to very cold bleak winds and rain. Leather is most suitable for very cold climates. Being impermeable they are extremely warm, but this impermeability prevents the ventilation and renewal of the layers of air confined under the clothing near the skin. The discomfort that arises from the wearing of waterproofs in warm weather is well known.

In hot climates the outer garments should be white or grey in colour to protect from the direct rays of the sun.

At the two extremes of life—in childhood and old age—warmth of covering is most essential. Children lose heat rapidly and are liable to chill, partly because the

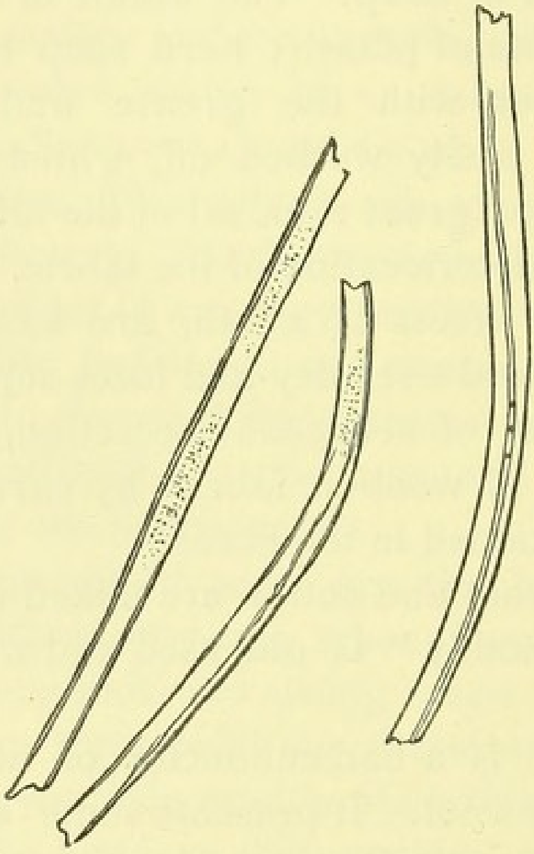

FIG. 66.—Silk Fibres × about 200.

circulation being rapid more blood is carried in a given time to the superficial vessels, and more heat is thus lost from the surface, than in an adult; but mainly because in children the surface of the body is larger in proportion to its bulk or contents, than is the case in adults. Consequently, a larger surface proportionally being exposed, from which heat can be radiated, children must be more warmly clothed than grown-up people. A simple example will serve to illustrate the above fact. If two cubes are taken with sides of one square foot and two square feet respectively, it is evident that the smaller cube exposes a surface of 6 square feet, and has a bulk of 1 cubic foot; or surface is to bulk as 6 to 1. The larger cube exposes a surface of 12 square feet, and has a bulk of a little less than 3 cubic feet; or surface is to bulk as 12 to 3, or 4 to 1.

The same is true when applied to cylinders which more nearly resemble the human body. If two solid cylinders are taken, both 10 inches in length, but the smaller having a base 1 inch in diameter, and the larger

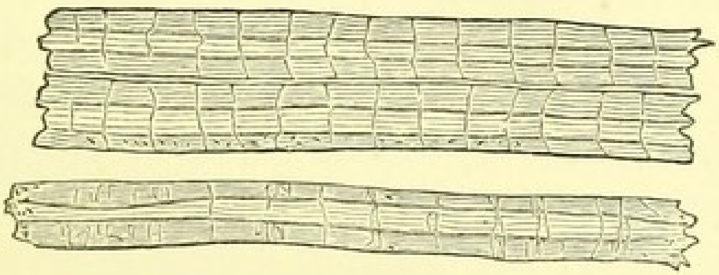

FIG. 67.—Hemp Fibres × about 200.

a base 2 inches in diameter; in the smaller cylinder, surface is to bulk as 33 to 8; in the larger, surface is to bulk as 66 to 32. That is to say, the larger cylinder has 4 times the bulk of the smaller, but only twice the surface.

Children should be clothed in woollen materials, and the legs, arms, neck, and chest should be equally protected with the other parts of the body.

In old age the circulation is often feeble and languid, and the functions of heat production and regulation are less efficiently performed than before senile decay commenced. Consequently if the body is chilled, the restoration to the normal heat is slow, and the vital functions are dangerously depressed.

Aniline dyes are now largely used for colouring various dress materials and under-garments such as stockings. As a rule the dyes used are free from arsenic; but it has occasionally happened that eczematous sores have been produced on the feet and legs by wearing dyed stockings, and there can be but little doubt that the sores were due to the absorption of arsenic through the skin when the feet were hot and damp.

CHAPTER IX.

THE CONTAGIA: COMMUNICABLE DISEASES AND THEIR PREVENTION: HOSPITALS.

THE CONTAGIA.

CERTAIN diseases of men and animals have long been known to be communicable from one individual to another, and recent investigations have shown that some of these diseases are not only communicable from one individual of the same species to another, but are interchangeable between animals and men, and between men and animals. Various doctrines have been held at different times as to the nature of the contagia in these diseases, but the theory of their constitution which is embraced in what is known as the "germ theory of disease" need only be discussed here, as being the most recent enunciation of the scientific study of disease causation, and as possessing certain easily intelligible inherent possibilities which are absent from the earlier beliefs on this subject. Whilst endeavouring to supply an explanation of such facts as are known about infection or contagion by the aid of the germ theory, it need not necessarily be assumed that any such doctrine is capable of satisfactorily explaining every occurrence in disease dissemination, or that a finite settlement of a very profound and complex subject has been arrived at. It is more than probable that the future will bring forth modifications and alterations in principle and detail, which will deprive the views, at present entertained, of much of that simplicity and easy intelligibility which is one of their chief recommendations to popular favour.

The germ theory, then, assumes that the contagia are microscopic living particles, organised in structure and for the most part capable of independent life both within and without the animal body. These organic particles are believed to form part of that large class the *schizomycetes*, which embraces the lowest and least developed forms of organic life in the animal kingdom, and constitutes a link, as it were, between the two great divisions of the animal and vegetable world. To this class belong the bacteria, bacilli, micrococci, spirilla, vibrios, etc., which exist in such enormous numbers in the air, water, and soil in every region and climate, and to which, in conjunction with yeasts and moulds (fungi), the fermentative and putrefactive changes, to which all organised structures are more or less liable, have been ascribed.

The probability of the view that the particles of contagia are really bacteriform organisms, is favoured by the analogy of the processes of typical infectious disease in the human body to those of fermentation in an organic liquid. When the yeast plant obtains access to a saccharine fluid and the temperature is suitable, the cells of the yeast rapidly multiply, and after a certain time, which corresponds with the period of incubation in an infectious disease, changes are produced in the saccharine liquid, evidenced by the formation of alcohol and carbonic acid, which eventually render it incapable of being further acted upon by that particular ferment. So in infectious disease, there is a period of incubation which may be supposed to arise from the delay necessary for the growth and multiplication of the contagious particles; during the course of the fever the pabulum suitable for the nutriment of the contagion is exhausted, or else the products of the activity of the contagious particles upon the cells of the body become in time directly poisonous to the contagia themselves, the fever terminates, and the body is rendered unassailable by a similar infection for months or years, or until the end of life.

It is evident that the contagion, once introduced into the animal body, grows and multiplies enormously. The least atom of infectious material serves to inoculate small-pox in a susceptible person, but the contagious matter produced in the course of the disease would be sufficient to inoculate many thousands. In each special disease the contagion multiplies chiefly in those tissues —the mucous and epithelial—which are more especially subject to its action, and the infection is cast off from the body in large part with the secretions of these tissues. Freed from the body the infection may be carried through the air from the diseased to the healthy, or it may lie dormant in the clothes or furniture of the sick-room for long periods, but retaining its contagious properties.

This property, possessed by some of the contagia, of retaining unimpaired their powers of infection for long periods after leaving the body, points strongly in favour of their bacterial nature. It is known that many bacteria are propagated by sporulation, and that the spores, the immature forms of the adult species, can resist extremes of temperature and drying which are destructive to the fully-developed organism. That liquids, gases, or any non-living material whatever, could retain infective properties for long periods after expulsion from the body, when subjected to the disintegrating forces of the atmosphere, is at least highly improbable.

In other cases the contagion leaves the body in the excretions of the bowels or possibly of the kidneys, and is propagated, not so much through the air, as by means of water or food to which the evacuations may have gained access. Whether under these circumstances the contagia can grow and multiply outside the animal body, as they undoubtedly do within it, is a point not yet definitely settled, but of which *primâ facie* there is a very considerable likelihood.

In yet a third class, the contagion does not appear to be capable of retaining an independent existence outside the animal body. In these cases the infection is conveyed by direct contact, *i.e.*, by inoculation from the diseased body to the tissues of the healthy. It is probable that all, or nearly all, the communicable diseases are inoculable, although the usual method of dissemination is, as the case may be, by air-borne or water-borne infection.

It is not desirable to retain the term contagious, as distinct from infectious, in regard to the communicable diseases. For if, as is generally understood, the term contagious is limited to those diseases which are only transferable by direct inoculation, and infectious to those that have air- or water-borne contagia, an element of confusion is introduced; for most of the infectious diseases are inoculable, whilst the diseases which are generally spread by inoculation, may at times be propagated through air or water. The term zymotic is usually limited to those communicable or infectious diseases which occur in epidemics; but here again, as zymotic commits us to the theory that the disease is dependent upon a living organised body of the nature of a ferment, it is not easy to understand why zymotic should not embrace the whole class of ailments in which a germ or microbial origin is considered probable.

The use of the word specific as applied to these diseases pre-supposes a specific origin for each—an origin, that is to say, from a pre-existing case of the disease by means of a specific virus or organised living germ. The specific origin of a majority of the communicable diseases can hardly be doubted. The eruptive fevers are specific, they breed true, *i.e.*, a case of measles, for instance, cannot give rise to mumps or whooping-cough, but only to measles, and the infection cannot arise *de novo*, but must be sought for in a pre-existing case. The true specificity of some, however, such as diarrhœa, dysentery, and the hospital fevers (erysipelas, pyæmia, etc.) may be doubted, as it is at least probable that such diseases can at times arise from ordinary decomposition of organic matters, untainted with the virus of a pre-existing case.

In the following table the communicable diseases are tabulated according to their more general mode of propagation by means of contagion carried in the air, or in water, or transmitted by direct inoculation.

The diseases in Class A include those usually known as the eruptive fevers, and are remarkable chiefly for occurring in epidemics, often at regularly recurring periods. The contagion being disseminated through the air, it is easy to understand how these diseases, once introduced into a community, spread with amazing rapidity, until the diminution of susceptible persons causes the epidemic to languish and finally die out.

Class B comprises diseases which at times take on epidemic extension and virulence but are mostly endemic; that is to say, they are habitually present in certain localities where conditions of excremental pollution of water, air, or soil, favour the passage of the specific virus from one individual to another, with the constant occurrence of isolated or sporadic cases, which, at certain seasons when external conditions are favourable, give rise to the sudden and wide-spread dissemination termed an epidemic. The introduction of public water-supplies into towns has, no doubt, tended to cause certain epidemics of enteric fever and cholera to reach further and spread wider than formerly; for if a public water-supply is specifically polluted at its source, the contagion is carried to a far larger number of households than could possibly be the case where each house has its own well or spring.

The evidence as to the communicability of tubercular diseases, including the destructive lung diseases, does not yet amount to complete proof, but is sufficiently strong to warrant the belief that the tubercular virus, under certain favouring conditions, retains its infective properties after discharge from the animal body, and can then be transferred to healthy persons through the medium of the air. The question of susceptibility to the tubercular virus is of the greatest interest, and is deserving of most careful investigation. It is evident that tubercle bacilli must be very widely scattered in the air of houses and towns, and yet the number of persons who contract tubercle is relatively infinitely small compared with the numbers that must from time to time be exposed to the contagion. Unlike the eruptive fevers, tubercular diseases run no definite course; and although it is now certain that recovery from tubercular lesions of the lungs, and perhaps of other organs, is by no means infrequent, yet there is no immunity conferred from subsequent attack, as in the case of the diseases in classes A and B, with the probable exceptions of erysipelas, diphtheria, epidemic pneumonia, and dysentery.

The diseases in Class C are more generally transferred from the sick to the healthy by means of inoculation than by any other method.

In Class D are included those fevers of hospital origin, which pass rapidly from patient to patient, provided there is a surface lesion or wound for the absorption of the virus (pyogenic organisms of various kinds), which are therefore extremely contagious, but absolutely non-protective against subsequent attack.

From the tabulated list there have been omitted oriental plague, dengue, cerebro-spinal meningitis, and other diseases of tropical climates not met with in this country.

Communicable Diseases.

Class		Diseases
A	Contagion usually air-borne.	Small-pox Scarlet Fever Measles Rötheln Mumps Chicken-pox Whooping-cough Influenza Typhus Relapsing Fever Diphtheria Erysipelas Epidemic Pneumonia
B	Contagion is air or water-borne.	Yellow Fever Cholera Enteric Fever Dysentery and Diarrhœa
C	Contagion usually by inoculation.	Anthrax or Malignant Pustule Foot and Mouth Disease Leprosy Glanders Rabies or Hydrophobia Vaccinia Ophthalmia Syphilis Gonorrhœa Tetanus
D	Surface lesion necessary for contagion air-borne or directly inoculable.	Erysipelas Pyæmia Septicæmia Hospital Gangrene Puerperal Fever
E	Contagion air-borne or by inoculation.	Tubercle (Scrofula, Lupus).

The subject of bodily susceptibility to the action of the various contagia, requires a passing notice. It is evident that in infancy and childhood the bodily susceptibility to various contagia is very great, and this susceptibility diminishes with advancing age. The protective influence of a previous attack in some diseases, the modifying influences of the state of health of the individual, of hereditary predisposition, and of individual or family idiosyncrasy, are well known to produce different conditions of bodily susceptibility; and there are other causes at work, less well known, but possibly equally potent. A plausible hypothesis as to the causes of these varying susceptibilities is the supposition that under these different conditions the vital actions of the body are not always equally potent to resist the invasion of the contagia. There is the battle of the cells of the body and the bacteria, in which victory lies to the strongest; the weakness of the cell forces in certain cases constituting the special susceptibility to the action of the virus.

The microbial origin of some of the communicable diseases may be considered to be established beyond doubt, and this fact is a strong argument in favour of the remainder—in which no such connection has as yet been positively traced—being causally dependent upon specific micro-organisms. Koch has laid down certain conditions, upon the proof of which alone can it be definitely stated that a particular micro-organism is the cause of a certain disease. They are as follows:—

1. The micro-organism must be found in the blood, lymph, or diseased tissues of man, or animal, suffering from or dead of the disease.

2. The micro-organisms must be isolated from the blood, lymph, or tissues, and cultivated in suitable media outside the animal body. These pure cultivations must be carried on through successive generations of the organism.

3. A pure cultivation thus obtained must, when intro-

duced into the body of a healthy animal, produce the disease in question.

4. In the inoculated animal the same micro-organism must again be found (E. Crookshank, *Bacteriology*).

It is evident that postulate no. 3 being inapplicable to human beings, the complete sequence of proof cannot be arrived at in the case of solely human diseases. But in the case of the diseases interchangeable between men and the lower animals, inasmuch as the animals can be submitted to processes of inoculation, the entire chain of proof can be substantiated, and is held to be equally applicable to the disease in man. The list of diseases of the lower animals, which are dependent upon specific microbes for their origin and propagation, is now very extensive, including fowl-cholera (micrococcus choleræ gallinarum), malignant œdema, pyæmia, septicæmia, and various suppurative diseases in rabbits, guinea-pigs, mice, etc., swine-fever (bacillus), foot and mouth disease (streptococcus), and many others.

To distinguish different specific bacteria from one another, microscopic appearances of size and shape—the morphology—must not be relied upon alone; but the reaction to staining fluids, and more especially the appearance and pigmentation of the growth of a pure cultivation in sterilised nutrient media such as broth, peptone-gelatine, agar-agar, or blood serum, and the temperature at which the growth takes place, must be largely relied upon.

The diseases of animals common to man, in which a specific bacterium has been isolated are anthrax (malignant pustule in man), tubercle, glanders, actinomycosis, erysipelas, and diphtheria.*

* Perhaps scarlet fever should now be included as a disease interchangeable between man and cows, see p. 323.

Anthrax, malignant pustule, or *wool-sorter's disease.*—The specific microbe is a bacillus with a curved or wavy outline and of large size, so that it is readily seen under moderate powers of the microscope. They are deeply stained by aniline dyes, and readily form spores when exposed to the air, which are very resistent to extremes of heat and drying, and to chemical reagents, unlike the fully developed bacilli. The bacilli are found in enormous numbers in the blood of animals dead of anthrax.

The disease is imparted to men engaged in handling the wool or hides of infected animals, either by direct inoculation of a wound or abrasion on the face and hands, which gives rise to the malignant pustule; or by inhalation of the dust, containing spores, into the mouth or lungs when general infection of the system follows, usually proving fatal in the course of a very few days. The symptoms of general infection are usually obscure, and appear to depend upon the organ with which the virus first comes in contact. If the dust is swallowed, the stomach and bowels are chiefly affected; if inhaled, the lungs. Bacilli are found in the serum of the pustule, in the various secretions, and in the blood after death.

Animals infected with anthrax should be at once slaughtered and their bodies burned. If buried, the carcase should not be opened, but left whole, as there is less likelihood of spore formation taking place; the bacilli themselves are probably destroyed by the putrefactive bacteria when decomposition has set in. The bacilli are present in large numbers in the discharges of infected animals, and undergo multiplication with spore formation in the surface layers of the soil, so that the strictest disinfectant measures are necessary to avoid the spread of the epizöotic through a herd of cattle or sheep.

In this disease as in some others such as chicken-cholera, rabies, and swine fever, the virus can be attenuated by cultivating the bacillus at high temperatures (42° C. or 43° C.) in sterilised nutrient media for a varying number of days, or by growing it in medicated gelatine—corrosive sublimate 1 part, gelatine 40,000 parts (Klein). When cultivated at 42° C., the bacilli produce no spores, and the intensity of their virulence decreases day by day. This attenuated virus (or it may be the waste products of its metabolism), when inoculated into susceptible animals, inhibits the growth of the specific microbes, and is so found to confer immunity for a time from the disease in its virulent form. The same result can be attained when the bacillus from one species of animal is passed through a different species. If the bacillus of sheep or cattle is inoculated into mice, the organisms taken from the mouse are attenuated for sheep and cattle, and confer immunity from subsequent attack.

Tubercle.—The bacillus tuberculosis is found in all tubercular deposits, and is seen with a high power of the microscope to consist of small, usually curved rods. They readily undergo spore formation. The bacilli are found in the sputa of phthisical patients; and in man the disease is set in action by the bacilli introduced, according to the usual method, through the mucous membrane of the lungs or intestinal canal, or occasionally by direct inoculation into a wound or abrasion of the skin.

In the lower animals (monkeys, cattle, fowls, guinea pigs, rabbits, etc.), artificial tuberculosis can be readily produced by inhalation of a spray containing tubercle bacilli, by feeding experiments with tuberculised food, and by direct inoculation, the channels of infection being the same as those of man.

Glanders.—The bacillus of glanders (*bacillus mallei*) consists of rods about the size of tubercle bacilli. The inoculation of pure cultivations into horses produces the characteristic disease, the bacilli being found after death in the affected organs and diseased tissues. In man the disease is set up by inhalation of the infected breath or nasal secretion of a diseased horse, or by direct inoculation into an abrasion of the skin.

Actinomycosis.—This is a disease of the jaws and sometimes of the lungs in cattle, characterised by the formation of hard nodular tumours, and is occasioned by the *actinomyces* or ray-fungus. The disease is transmissible in cattle by inoculation, and is, very rarely, imparted to man, when the lungs seem to be primarily affected, new formations appearing and rapidly breaking down.

In *erysipelas* a streptococcus has been found occupying the lymphatics of the skin at the circumference of the erysipelatous blush. A pure cultivation of the streptococci produces erysipelatous inflammation when inoculated into animals and into men, as has been done for the relief of lupoid and cancerous affections.

Roux and Yersin have isolated a bacillus from the surface of the mucous membrane in cases of *diphtheria.* From cultivations of this bacillus a soluble poison has been obtained, which causes the symptoms of diphtheria in varying degrees of intensity according to the dose. This poison is not an alkaloid—a ptomaïne—but appears to be allied to the ferments, as it is destroyed by boiling for 10 minutes.

There are some other diseases, whose microbial origin is not yet definitely established, but in which there is a very strong probability of such a mode of occurrence. Chief among these is *leprosy.* In this disease fine rod like bacilli, many of which have spores, are found in enormous numbers in the tubercular lesions. They probably spread through the body by means of the lymphatics, as they are not found in the blood. The inoculability of the virus of leprosy has lately been demonstrated by the case of a condemned criminal in the Hawaiian Islands, who, to save his life, submitted to the operation in November, 1885, and is now reported to be a confirmed leper.

From vaccine lymph a streptococcus has been isolated, which is believed to be the specific organism of *vaccinia ;* from acute abscesses, boils, carbuncles, the abscesses of pyæmia, acute osteo-myelitis, and puerperal fever, the *staphylococcus pyogenes aureus* and *albus* have been obtained, which are pathogenic to certain animals ; a bacterium (pneumococcus) has been found in the exudations of croupous pneumonia, which is pathogenic to mice ; in ulcerative endocarditis a micrococcus has been observed in the endocardial ulcerations ; in Asiatic cholera, Koch discovered a comma-shaped bacillus in the intestinal walls and evacuations ; in enteric fever, bacilli have been recovered from the inflamed Peyer's glands ; in relapsing fever, a motile spirillum (*spirillum Obermeieri*) has been found in large numbers in the blood during the relapses, which is absent in the non-febrile periods, and which, when inoculated into monkeys, induces a disease analogous to human relapsing fever; and in malaria, a bacillus has been described by Klebs as being present in the blood of ague patients, which is also found in soils known to be malarious. A streptococcus is believed to be the specific microbe of scarlet fever (Klein) ; in cases of tetanus a bacillus has been isolated; and various micro-organisms have been described as associated with other diseases.

With the exception of scarlet fever, relapsing fever, leprosy, suppurative and septic diseases, which rest upon a surer basis, there is still wanting, in the case of all these diseases, the complete chain of experimental proof necessary to establish the causal relationship of the organisms which have been described as associated with them. The experimental inoculation of the lower animals with the supposed viri of human diseases to which they are not known to be naturally liable, affords little or no assistance to the completion of the proof, even if symptoms are produced in the animal of an analogous nature to those characteristic of the disease in man. The constant association of a certain organism with a certain disease, in all climates and races of men, is, no doubt, practically a strong point in favour of the specific nature of the microbe, but logically it does not prove that the microbe is an indispensable antecedent (cause), or even an antecedent (one of several causes in conjunction) of the disease, or indeed that it is anything more than a consequence.

Recent research seems to point to the symptoms of infectious disease being caused not directly by the action of the microbes themselves upon the tissues, but by the production of soluble poisons of the nature of alkaloids (ptomaïnes) or of chemical ferments. Observations have already been made in the cases of anthrax, tetanus, diphtheria, puerperal fever, and rabies, that these diseases are—or may be—caused by the specific microbes producing, as the result of their activity, soluble poisonous alkaloids or ferments which exert a direct action upon the tissues of the body; and if such is the case in these diseases, the symptoms of many others of an allied nature may also be due to the chemical products of the microbes, and not to the direct action of the microbes themselves upon the tissues. There is a matter of practical interest involved in this point, for although the microbes themselves may be destroyed by boiling or other application of heat, their chemical products can resist these high temperatures, and retain their poisonous powers unimpaired. Still, as far as our knowledge at present extends, the microbes, although only the makers of the poisons which directly affect the body, are the principal or only means of spreading infection.

On the introduction, then, of the microbes of specific disease within the body of an animal, we may assume that poisonous products are sooner or later produced. Whether the disease will develope, and what form of mildness or severity it will assume, appears to depend upon the powers of the white corpuscles or leucocytes of the bodily fluids to grapple with these toxic products. Should the animal have already undergone preventive inoculations with attenuated virus, it appears that the leucocytes, having already become accustomed to the microbic poisons, are able to struggle with and devour the parasites on their entrance, and the disease is not developed.

The decline of an infectious disease is very probably connected with the accumulation in the body of the toxic products of the microbes, which tend in time to destroy their life and activity; for we know that putrefactive bacteria produce, by their action upon albuminous substances, certain antiseptics, amongst which are cresol, indol, skatol, and compounds of phenol, which destroy these organisms, and the reasoning may be extended by analogy to the pathogenic microbes.

Preventive inoculations may be made with attenuated virus, *i.e.*, with cultures of the microbes weakened by exposure of successive generations to heat, not sufficient to destroy them altogether, or by growing the microbes in culture media medicated with some antiseptic, or by passage of the microbes through animals of different species; or the inoculations may be made with the soluble chemical poisons produced by the virus during its growth in nutrient media. Preventive inoculations by the latter means alone have already been carried out in the case of anthrax, chicken cholera, diphtheria, and mouse septicæmia; and the attenuated virus of rabies (Pasteur's method) is probably only the chemical products of the microbes growth, and not any form of the microbe itself.

Communicable Diseases.

Small-pox and Vaccination.

The incubation period of small-pox is about 12 days; when the virus has been inoculated, the incubation is shorter—only 7 or 8 days. Small-pox is communicable from the earliest appearance of the symptoms, and the ordinary duration of infectiveness is from 3 to 4 weeks. There can be little doubt that the contagion is most active, and the infectivity greatest, during the period of maturation and crusting of the pustules. The virus is contained in the breath of the patient and in the skin eruptions, and may be conveyed for considerable distances through the air in the dried epithelial scales and pus cells from the crusted pocks.

The exceptional incidence of small-pox in the immediate neighbourhood of some of the London small-pox hospitals (investigated originally by Dr. Thorne Thorne), in which were formerly treated during epidemic periods large numbers of cases, many of them in the acute stages, can admit of but one explanation, *viz.*, that when a sufficient number of cases in the acute stages are collected together in one building on a small area of

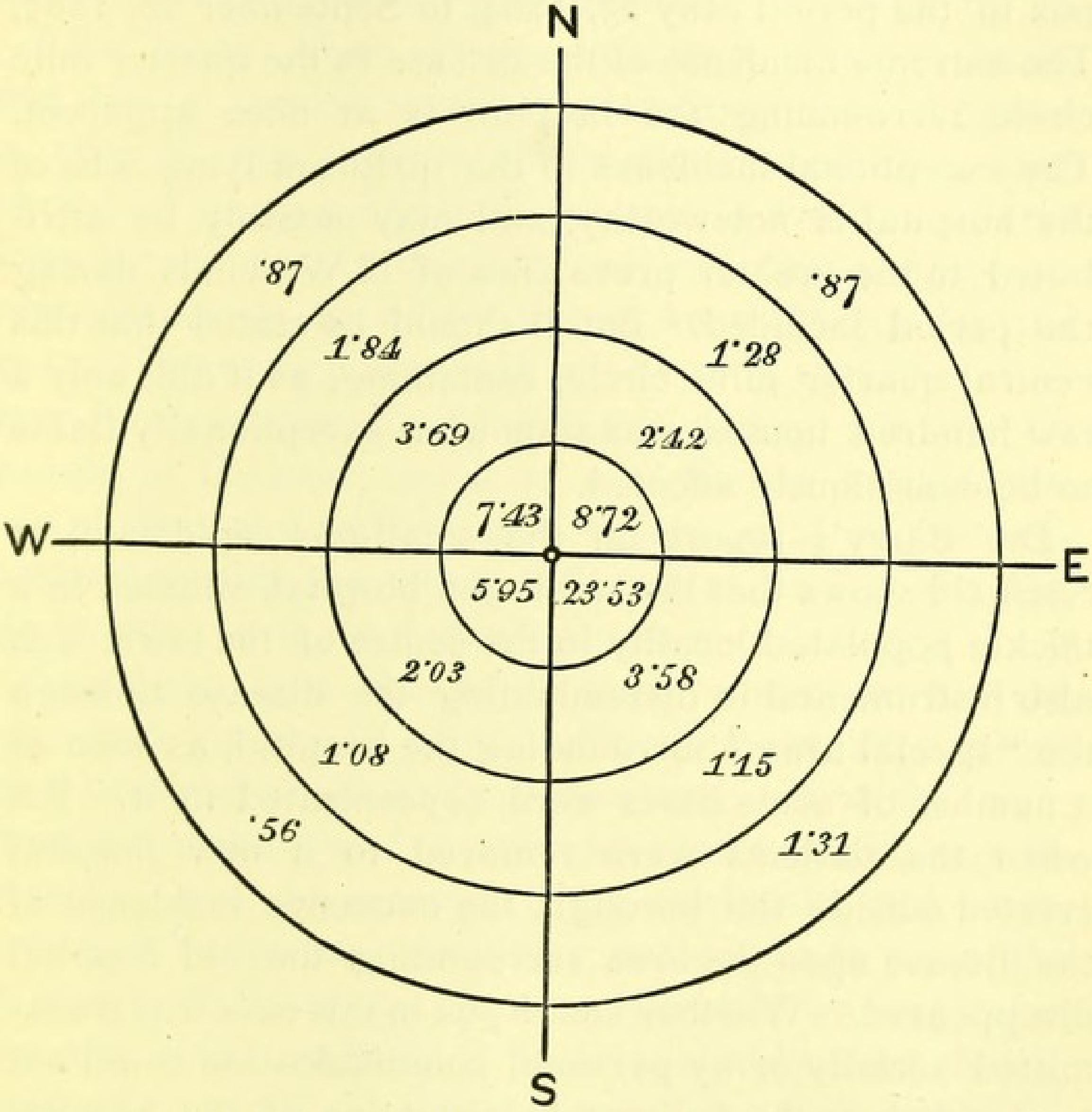

FIG. 68.—Fulham Small-Pox Hospital: Special area divided into sections of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1 mile radius; showing in different areas number of houses (out of every 100) invaded by small-pox, in the period, May 25, 1884 to Sept. 26, 1885.

ground, the hospital becomes a centre of infection to the surrounding neighbourhood, the virus being almost certainly transmitted through the air by means of currents and winds. In the diagram (fig. 68) taken from Mr.

Power's Report to the Local Government Board, 1885, the neighbourhood around the Fulham small-pox hospital is divided into special areas by circles of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 mile radii. In these special areas, the figures show the percentage of houses in each area invaded by small-pox in the period May 25, 1884, to September 26, 1885. The extreme incidence of the disease in the quarter mile circle surrounding the hospital is at once apparent. The exceptional incidence in the quadrant lying S.E. of the hospital is noteworthy, and may possibly be attributed to the greater prevalence of N.W. winds during the period included. But it should be stated that this central quarter mile circle, containing, as it did, only a few hundred houses, was somewhat exceptionally liable to be capriciously affected.

Dr. Barry's report on the small-pox epidemic at Sheffield shows that the small-pox hospital, situated in a thickly populated locality in the centre of the town, was also instrumental in disseminating the disease through the "special area" surrounding the hospital, as soon as a number of acute cases were concentrated in it. But when the patients were removed to a new hospital erected outside the borough, the excessive incidence of the disease upon the area surrounding the old hospital disappeared. Whether small-pox in this case was transmitted aërially or by personal communication could not be decided, as the faulty administration of the hospital might have allowed the transmission of small-pox by the persons of the hospital officers, or of visitors to the hospital.

The contagion clings persistently to infected clothing, bedding, and furniture, and is often communicated by means of these infected articles.

In recent times, small-pox appears to have a tendency to become epidemic in a community once every 10 years or so. Before the introduction of vaccination, small-pox epidemics occurred once every 3 years and possibly oftener, and were attended with a fatality and injurious consequences, such as loss of eyesight, which it is difficult at the present time to realise.

Like many other specific infectious diseases, small-pox has a special seasonal prevalence (see diagram p. 384, fig. 69). From observations covering a long period of years it has been possible to describe a curve showing the weekly mortality of this disease as a percentage above or below the mean mortality for the year. From the diagram it will be seen that the average London mortality is greatest during the first six months of the year, rising to a maximum towards the end of May and falling through June, until it descends below the mean line where it fluctuates during the last six months, to again rise in December or January.

Small-pox is a disease of every climate and every race, and attacks all ages and both sexes unprotected by a previous attack or by vaccination. It arises solely from the contagion of a previous case, and although its severity may be intensified by uncleanly and over-crowded houses and insanitary surroundings, as is the case with all infectious diseases, it cannot be originated by any such conditions. It is probable that during epidemic periods small-pox is very frequently spread by the number of mild and not easily recognisable cases of the modified disease in vaccinated persons that invariably occur. The virus from such mild forms is capable of imparting a very virulent form to unvaccinated persons, and the same holds true of nearly all infectious diseases. The mildest types often propagate contagion of the most virulent description.

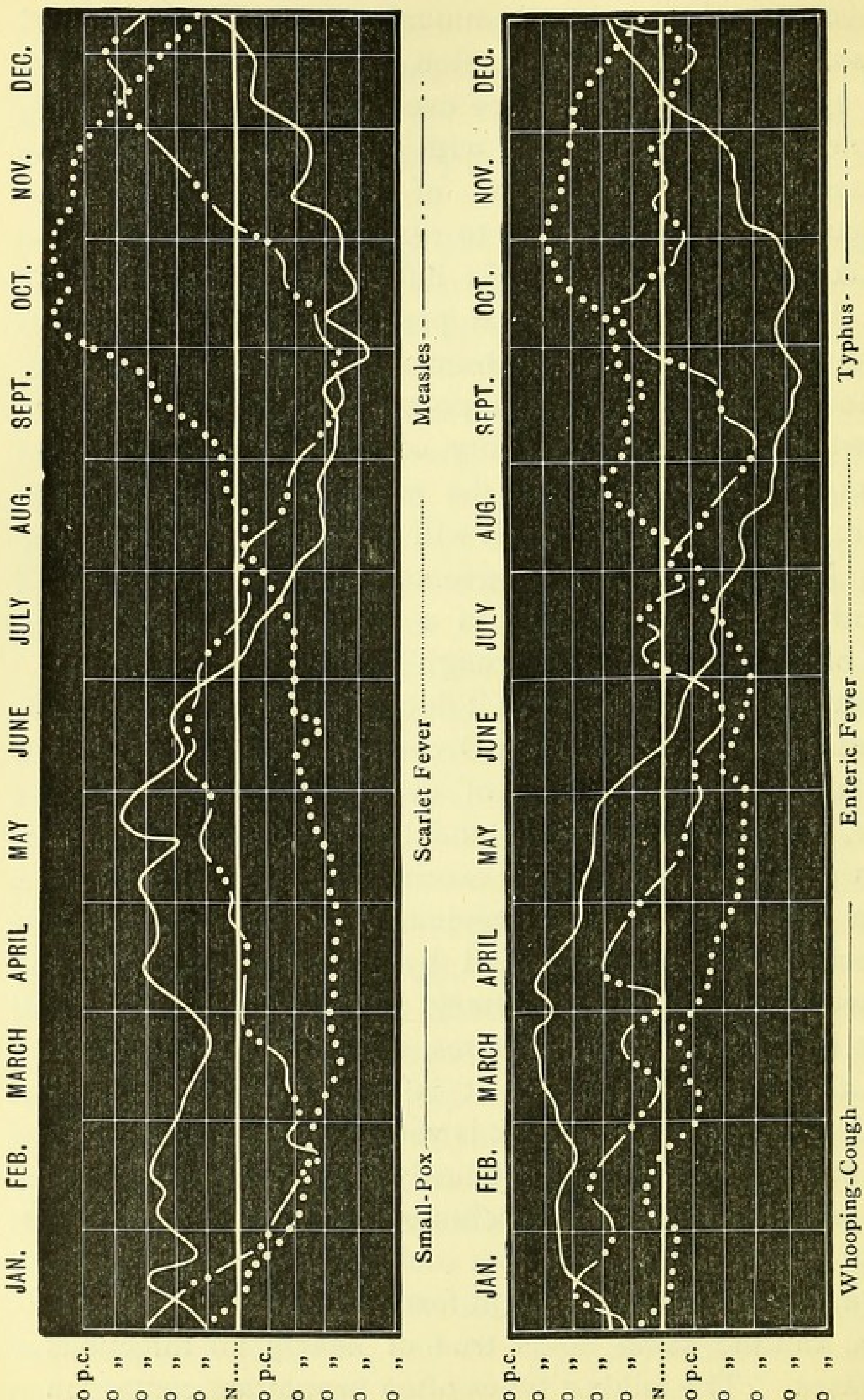

FIG. 69.—The curves represent the average death-rates in corresponding weeks of a period of years, calculated in percentages of the mean weekly death-rate of the whole period (after Buchan and Mitchell).

Previous to the discovery by Jenner, towards the end of the last century, of the protection afforded by the inoculation of cow-pox lymph against the attacks of small-pox, small-pox was a disease from which few escaped. From 1750 to 1800 small-pox caused nearly one-tenth of the total number of deaths (96 out of every 1000 deaths from all causes), and in epidemic years—1796 for example—this fatality was occasionally nearly doubled. So universal was the disease, and so frightful its disfiguring effects and the risk of loss of sight, that the practice of inoculation, introduced originally from Constantinople by Lady Mary Montagu, became very general during the latter half of the 18th century. The fatality of the disease so imparted was found to be much less than that of natural small-pox—2 or 3 per cent. of the cases ending fatally instead of 20 or 30 per cent.; but the infection was enormously multiplied all over the country, and the epidemics became more frequent than ever.

Jenner published the result of his researches in 1798, and since that time vaccination has made steady progress throughout all classes of the population with the result of gradually diminishing the frequency of epidemics, the severity of the disease, its incidence on the population, and its death-rate. In 1838 gratuitous vaccination was provided, and in 1853 vaccination became compulsory for all infants above the age of 3 months; but it was not until 1871 that Boards of Guardians were obliged to appoint public vaccinators for their districts. From 1838 to 1853 the death-rate from small-pox in England and Wales averaged 0·42 per 1000 persons living; from 1854 to the present time the average is not more than 0·2 per 1000. At the same time the proportion of small-pox deaths to deaths from all causes has fallen gradually from nearly 100 per 1000 (or $\frac{1}{10}$) in the last century, to an average of about 10 per 1000 (or $\frac{1}{100}$) from the year of compulsory vaccination to the present time (1889). The average death-rate from small-pox in the last century was probably not less than 3 or 4 per thousand. During the 8 years 1881-88 the average death-rate in England was only 0·05 per 1000.

This great decline in the mortality from small-pox is, however, entirely confined, as regards the last 40 years, to the early periods of life (under the age of 10). Under the age of 5 years the death-rate from small-pox has even been reduced 80 per cent. in the last 30 years. But above 10 years of age, the death-rate has increased, and has indeed largely increased at all ages subsequent to 15 years. The explanation is obvious. Compulsory vaccination in infancy has saved the lives of an enormous number of children, who formerly died of small-pox, and has served to reduce the death-rate from small-pox at all ages. After the age of fifteen the protective influence of the primary vaccination has to a large extent disappeared, and unprotected adults form a larger proportion of the population than in the earlier periods, when an attack of small-pox in childhood was far more common.

It was at first thought that one vaccination afforded protection to the individual against small-pox for the rest of life. This is now known not to be the case, with regard to infantile vaccination at least. In the first place, the efficacy of vaccination depends largely upon the efficiency of the operation and the number and character of the resulting scars. Secondly, the protective influence wears away with the lapse of time, and re-vaccination at the age of puberty is a measure whose utility cannot be doubted. Calf-lymph and that from a vaccine vesicle of the 8th day from a healthy infant, if used perfectly fresh, are probably capable of giving equally good results.

The protective effects of vaccination have been studied chiefly in relation to the fatality and severity of the disease in the vaccinated and unvaccinated. But this, it must be remembered, is only one side of the question, and the relative incidence of the disease on these two classes, is deserving of study. The exact proportion of unvaccinated to vaccinated in the community is not exactly known, but taking it at its highest figure, the unvaccinated cannot form more than 5 per cent. of the total population. On the other hand, the unvaccinated certainly form not less than 30 per cent. of the cases treated in small-pox hospitals, and the proportion of severe and hæmorrhagic cases is far larger amongst the unvaccinated than the vaccinated.

The fatality of the disease in the two classes is illustrated in the diagram, founded on figures supplied by Dr. Collie for the two epidemic years of 1871 and 1881, of cases treated in London small-pox hospitals (fig. 70). Under 15 years of age and over 15 years, the mortality per cent. of cases in the unvaccinated is nearly identical, viz., 37 or 38 per cent.; whilst under 15 the influence of the number and character of the scars in the vaccinated is seen to be of not nearly so much importance as over 15. The evanescence of the protective influence of primary vaccination after the age of 15 is thus well exhibited; for whereas one or more bad marks reduces the mortality to 4 per cent. under 15, over 15 the mortality of cases with one or more bad marks is 10 per cent.

Re-vaccination at puberty, if properly performed, confers almost absolute immunity from small-pox for the remainder of life, and if by any chance a re-vaccinated person should acquire small-pox, the disease assumes its mildest type. In Prussia, since the year 1874 when vaccination and re-vaccination became compulsory, the death rate from small-pox has been reduced to $\frac{1}{10}$ of its former rate, viz., from 0·24 per 1000, to 0·02 per 1000; and it is stated that in the Prussian Army

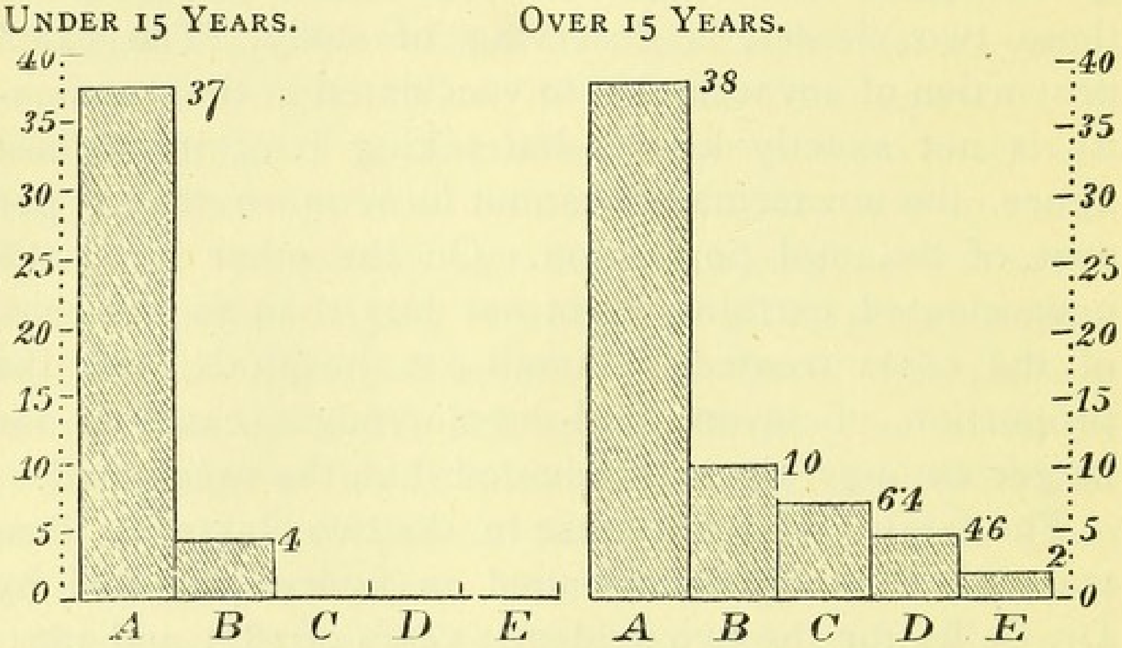

FIG. 70.—Small-pox epidemics, 1871, 1881. Mortality per cent. in Fever Hospitals (London).

— 15	+ 15	
(386)	(174)	A = unvaccinated.
(222)	(483)	B = one or more bad marks.
(76)	(141)	C = one good mark.
(44)	(151)	D = two good marks.
(70)	(100)	E = three good marks.

there has not been a single death from small-pox from 1874 to the present time.

The operation of vaccination, if properly performed with clear fresh lymph, does not impart any other disease but vaccinia. Erysipelas has been stated to have been caused by vaccination, but this might have happened in any other operation involving a surface lesion, and is certainly a very uncommon sequence of vaccination. The inoculability of syphilis with vaccinia, where the lymph is taken from a syphilitic child, is theoretically possible, but as a matter of practical moment, with the precautions everywhere taken, such an occurrence is almost impossible.

It is probable that if vaccination is performed on a person who has already contracted small-pox, within 48 hours of the exposure to contagion, vaccinia ensues and small-pox is avoided. But if performed at a later date small-pox is contracted, modified if within 3 days, but unmodified if later, with vaccinia possibly running its own course at the same time.

The evidence in support of the view that cow-pox is human variola modified by its occurrence in the cow is somewhat conflicting, experimental observations on the production of vaccine vesicles in the cow by inoculation with human variolous matter having usually failed. Whatever the original origin of cow-pox in the bovine species, it is certain that the disease is now transmitted directly from animal to animal, and that its origin from human small-pox is an event of very rare occurrence, if it ever happens at all.

Scarlet Fever.

This is a specific infectious disease like small-pox, its propagation being dependent upon a specific contagium derived from a previous case of the disease, if we except its possible origin from a certain diseased condition of cows and probably other animals. The incubation period of scarlet fever is short, probably not more than 2 or 3 days, or even less than 2 days. Infection is given off in the breath and from the skin of the patient during the whole period of illness, but the desquamative stage of the fever is probably the most infectious. The contagion clings with great pertinacity to the clothes, bedding, and furniture of the sick room, but is not capable of diffusion and dissemination through the air without loss of virulence like the small-pox contagium. The usual duration of infectiveness in scarlet fever is from 6 to 8 weeks, lasting throughout convalescence, and possibly prolonged by the occurrence of renal or other complications. In large towns, scarlet fever epidemics tend to recur every few years as a fresh series of susceptible children become exposed to the contagion.

Scarlet fever is more especially a disease of childhood. The influence of age, sex, and season upon the incidence and fatality of the disease has been elucidated by the Registrar-General (Annual Report for 1886), Dr. Whitelegge, Dr. Longstaff, Dr. Ballard, and other observers. The facts may be thus summarized :—

The mortality from scarlet fever is greatest in the 3rd year of life, and after this diminishes with age, at first slowly and afterwards rapidly. This diminution is due to (1) the increased proportion in the population at each successive age-period protected by a previous attack; (2) the diminution of liability to infection in successive age-periods of those who are as yet unprotected; (3) the diminishing risk in successive age-periods of an attack, should it occur, proving fatal. The liability of the unprotected to attack is small in the first year of life, increases to a maximum in the 4th or 5th year, and then becomes rapidly smaller and smaller with the advance of years. The chance that an attack will terminate fatally is highest in infancy, and diminishes rapidly with years to the end of the 25th year, after which a well-marked attack is again somewhat more dangerous. The female sex throughout life is more liable to scarlet fever than the male sex, but the attacks in males, though fewer, are more likely to terminate fatally.

The proportion of fatal cases to attacks of scarlet fever cannot be accurately stated, owing to the large number of unrecognised cases of very mild type, often without skin eruption and with very little desquamation. If all such cases of infectious sore-throat without eruption, which are by no means uncommon in adults or those who have been partially protected by a previous attack, could be included, the case mortality (proportion of deaths to attacks) would probably be found to be not greater than 1 or 2 per cent. These very mild and unrecognised cases are, doubtless, most frequent sources of dissemination of infection, and the fact of their being true scarlet fever cannot be doubted.

For the 10 years 1871-80, the death-rate from scarlet fever per 1000 living at all ages was about 0·7. Under 5 years the death-rate was 3·5 per 1000; between 5 and 10 years it was 1·5 per 1000, decreasing in the next quinquennium to 0·32 per 1000. During the eight years 1881-88 the average death rate in England from scarlet fever was 0·36 per 1000 living at all ages.

Unlike small-pox in unprotected communities, scarlet fever is a disease from which very many people altogether escape. The importance of saving young children from attacks of scarlet fever has been well expressed by Dr. Whitelegge.*

"In shielding a child against infection during the first few years of life there is a double gain; every year of escape from scarlet fever renders him less and less sus-

* Age, Sex, and Season in relation to Scarlet Fever. *Transactions of the Epidemiological Society*, vol. vii.

ceptible, until finally he becomes almost insusceptible; and, secondly, even if he should ultimately take the disease, every year that the attack is deferred reduces the danger to life which it brings. In other words, attacks of scarlet fever become both less severe and less frequent with every year of age after the fifth. Up to the fifth year the liability is less (than in the fifth year), but the risk to life in case of attack is very great." The same reasoning applies with almost equal force to measles, whooping cough, and the other infectious complaints of childhood.

Overcrowding and insanitary conditions in houses tend to aggravate the severity of scarlet fever attacks, and possibly aid in their dissemination, but can have no influence *per se* in originating an outbreak.

Scarlet fever is most prevalent and most fatal in the autumn, in the months of October and November. Two curves may be formed; one expressing the weekly or monthly deaths as percentages of the average weekly or monthly mortality throughout the year (fig. 69); the other expressing the number of weekly or monthly cases as percentages of the weekly or monthly average of cases throughout the year (fig. 71). These curves correspond very closely, but Dr. Whitelegge has noted that the mortality-curve rises less and falls less above and below the mean than the case-curve—which would imply that when most prevalent scarlet fever is least fatal and *vice versâ*. There is, at least, a strong probability in favour of this view, as the number of mild cases is usually greatest when scarlet fever is most prevalent.

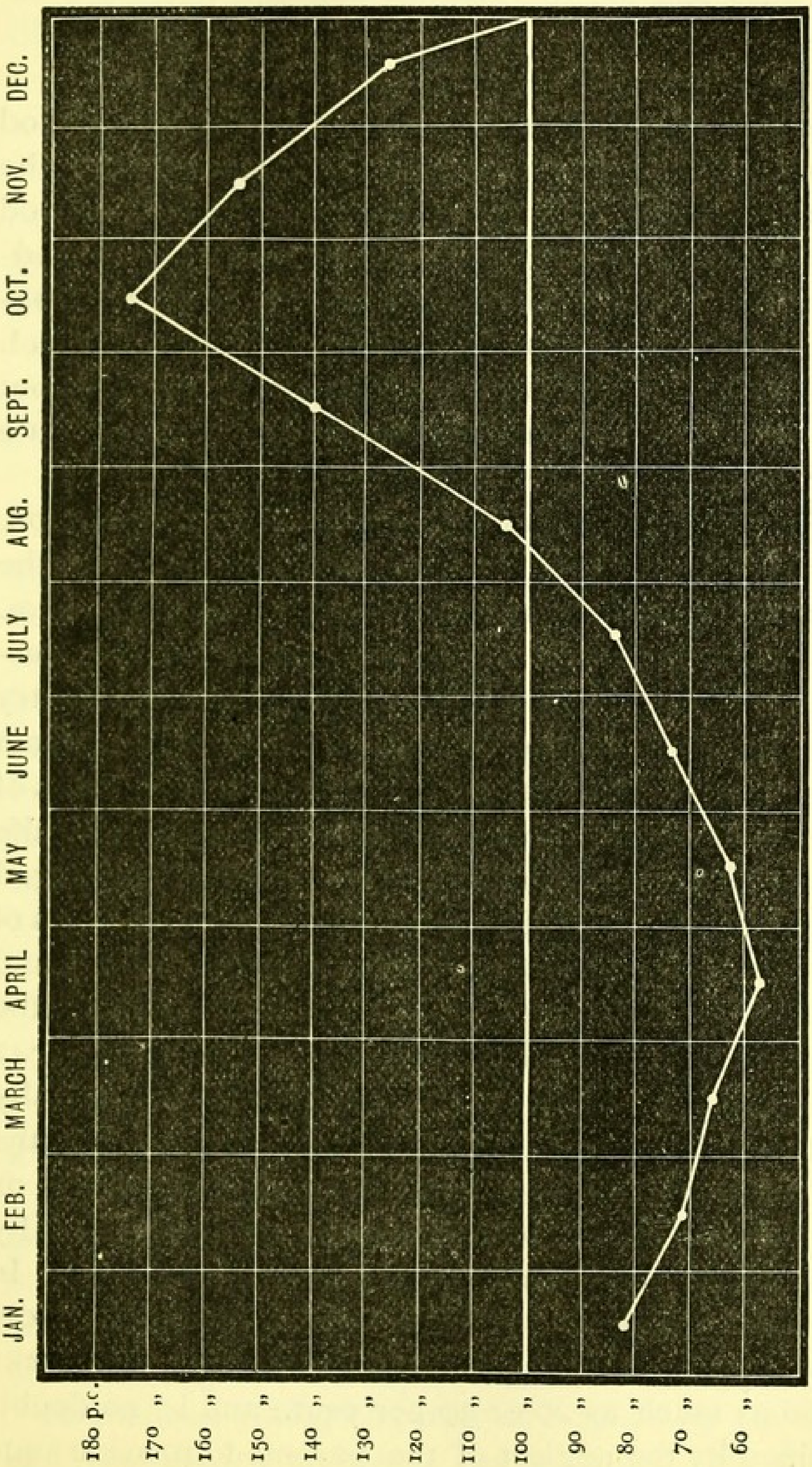

FIG. 71.—Seasonal curve of cases of scarlet fever stated as percentages of monthly average, based upon 23,000 cases notified in nine large English towns, 1885-6-7. (B. A. Whitelegge, *Epidem. Soc. Trans.*, vol. vii.).

Measles.

A specific infectious fever with an incubation period of 9 to 12 days. The contagion is given off from the breath and skin of the patient during the whole period of illness (3 or 4 weeks), and the catarrhal stage preceding eruption is especially infectious. It is for this reason that epidemics of measles are so difficult to control. The infection is not widely diffusible in the air, but clings to clothes and garments with a persistency little if any less than that of scarlet fever.

Measles is a disease of infancy and early childhood, and is very fatal to young children, chiefly owing to the frequency of pulmonary complications and sequelæ. Adults unprotected by a previous attack are also susceptible, but the disease is so universal in this country that few children escape from it. The mortality from measles is greatest under 3 years of age; after 5 years of age the mortality is enormously diminished. During the 10 years 1871-80, the death-rate from measles averaged about 0·38 per 1000 living at all ages; under 5 years of age the death-rate was 2·5 per 1000, and between 5 and 10 years only 0·2 per 1000. In the 8 years 1881-88, the average death-rate in England from measles was 0·42 per 1000 living at all ages. Both sexes are equally liable to attack, and the case-mortality is about the same for both. In this disease the case-mortality, or proportion of deaths to attacks, is greatly affected by overcrowding and insanitary conditions generally. In the overcrowded houses of the poor, amongst badly nurtured children, the proportion of deaths to attacks may be as much as 20 or 30 per cent., and is, no doubt, intensified by the neglect of the parents to provide suitable warmth and nourishment for the sufferers from a disease which they think of little moment. In healthy houses, well-nourished children almost invariably make a good recovery.

Measles is most prevalent and most fatal in the winter months of November, December, and January; but it also tends to become somewhat intensified in the late spring (May and June), see p. 384, fig. 69.

Measles epidemics tend to recur in large towns about every 3 or 4 years, with the fresh appearance of susceptible children.

Rötheln, Rubella, or *German Measles.*—This is a specific infectious fever, propagated by a specific contagium, and not a hybrid between measles and scarlet fever, from either of which diseases it is entirely non-protective. It has an incubation period of 10 to 14 days, and is infective during the whole course of illness (7 to 14 days). It is not a disease of common occurrence, and the illness produced is almost invariably very mild. It is probable that children and young adults are most susceptible.

Whooping-Cough.

This is a specific infectious disease, the infection being given off in the breath and secretions from the lungs. It is probably not carried far in the air, but clings pertinaciously to articles of clothing. The period of incubation may last from 1 to 3 weeks, and the period of infectiveness is usually not less than 6 weeks from the onset of cough, and may be longer.

Infants and young children are specially susceptible, and few escape attack. The younger the child the greater is the likelihood of the attack proving fatal; 40 per cent. of the mortality from whooping-cough occurs in the first year; 30 per cent. in the second; 15 per cent. in the third; 6 per cent. in the fourth, and so on (Squire). Girls suffer more proportionally from severe attacks than boys. In the first two years of life the proportion of deaths to attacks cannot be less than 10 per cent., and is probably higher. After the third year this proportion is not more than 2 per cent. Adults seldom suffer, as the protection afforded by an attack in childhood is so universal; but if unprotected they are equally liable with children.

Whooping-cough is now the most fatal of all the infectious complaints of childhood under the age of 5 years. For the period 1871-80, the death-rate was 3·6 per 1000 under 5 years of age, (scarlet fever being 3·5); and the death-rate for all ages was 0·5 per 1000. Between 1881 and 1888 the death-rate for all ages averaged 0·44 per 1000.

Whooping-cough occurs in regularly recurring epidemics every few years, but it has an exceptionable prevalence and fatality in the spring. The seasonal curve attains its maximum late in March or early in April, and from that point rapidly declines (see p. 384, fig. 69).

Typhus.

A specific contagious disease, but almost invariably found to be associated with conditions of filth and overcrowding in large towns amongst poor working-class populations.

The usual period of incubation is a week. The infection is contained in the exhalations from the lungs and skin, and is transmitted through the air from the sick to the healthy; but it is rapidly destroyed by dilution with fresh air, and does not cling to articles of clothing, so that in a well-ventilated house typhus rarely spreads from the original case. The female sex and the period of 10-25 years appear most susceptible, but neither sex nor age are protected from attack. A case of typhus may spread infection for 3 or 4 weeks subsequent to the onset of the disease.

Being so closely associated with overcrowding, typhus increases in intensity during cold weather and during periods of want, when there is an inducement for many people to huddle together to keep warm. In some of our large towns, epidemics recur in certain poverty-stricken quarters with considerable regularity, as fresh susceptible cases arise.

The mortality from typhus has undergone an enormous diminution in this country during the last 20 years. Before 1869, typhus, enteric fever, and simple continued fever were included together in the Registrar-General's returns under the generic heading of "Fever"; but since that date, mortality returns of these three diseases have been presented separately. In 1869 the death-rate from typhus in England was 0·193 per 1000 living at all ages; between 1881 and 1888 the average typhus death-rate was only 0·020 per 1000; that is to say, it has fallen to $\frac{1}{9}$ of its former rate in the space of 20 years.

Simple continued fever is, probably, in a large majority of cases, a convenient term for the registration of deaths due to undiagnosed and obscure cases of fever, such as may occur in typhus, general tuberculosis, septicæmia, pneumonia, and intermittent fever. Dr. Longstaff is of opinion that only a very small proportion of these deaths, if any, are due to enteric fever (*Epid. Soc. Trans.*, 1884-5). Simple continued fever, as a cause of death, exhibits a decrease in the last 20 years closely analogous with that of typhus (1869, death-rate was 0·24 per 1000; 1887, death-rate was 0·018). This decrease is, no doubt, largely due to greater precision in diagnosis, but may, to a certain extent, be due to the diminishing prevalence of a definite disease.

Diphtheria.

The etiology of this disease is still veiled in obscurity. Whilst, on the one hand, it cannot be doubted that diphtheria is contagious, the contagion being transmitted from the sick to the healthy; on the other hand, diphtheria outbreaks at times appear to originate independently of the infection of a pre-existing case, and to be causally related with the effluvia arising from decomposing animal or vegetable substances, or with excessive moisture of soils or sites of houses. It must be remembered, however, that the diphtheria contagion probably has the power of lying latent for long periods of time, with the capacity of renewing its virulence under suitable conditions of environment, and that, as in the case of enteric fever, mild and unrecognized forms of the disease may deposit the virus in the most unlikely localities. When roused again into action, with the production of a diphtheria outbreak, such an occurrence might well be believed to have originated *de novo*.

Diphtheria occurs endemically in certain localities, epidemic extensions taking place from time to time. It is a matter of observation that certain rural districts in which the soil is cold and humid, and where damp houses and drainage nuisances abound, are particularly favoured by diphtheria. Until lately it was regarded as being to a far greater extent a rural than an urban disease; but the continuous steady increase of the disease in London and its suburbs (in 1888 the death-rate was 0·3 per 1000), as well as in many other urban districts, is evidence that it finds a suitable soil for development in towns, despite the drainage of the subsoil water by sewerage and the presence of smoke in the air—factors hitherto believed to be of importance in its prevention.

The incidence of the disease is most marked on children between the ages of 2 and 10 years, and subsequently decreases with every year of advancing age. During the 10 years 1871-80, the average death-rate in England from diphtheria was 0·12 per 1000 living at all ages; under 5 years the death-rate was 0·47 per 1000; and between 5 and 10 years 0·29 per 1000. In the 8 years 1881-88, the average death-rate from diphtheria was 0·15 per 1000 living at all ages. As a rule, the younger the child the greater the chance of an attack proving fatal.

School attendance is a very potent factor in the spread of diphtheria. At the commencement of an outbreak, apparently simple cases of tonsillitis are instrumental in disseminating the disease; and there can be but little doubt that these cases, although unrecognisable as such, are either true examples of diphtheria, or that a virus is developed in the course of such simple cases of sore-throat that is capable of propagating the contagion in its most virulent condition.

Diphtheria epidemics are occasionally inextricably mixed up with outbreaks of scarlet fever and measles. The occurrence of scarlet fever and measles appears to greatly predispose the sufferer to become receptive of the diphtheria contagion, which may be present in a locality together with the poison of either of the other diseases. There is no reason to believe that diphtheria is in any way interchangeable with scarlet fever or measles, in the sense that the infection of one disease may produce the other. The diphtheritic contagion is given off from the body in the breath and secretions from the mouth and throat, and although probably not far diffusible in the air, clings with great pertinacity to infected articles of clothing and bedding.

As is the case in some other infectious maladies, there appears to be in certain individuals a peculiar hereditary or family susceptibility to attacks of diphtheria. The incubation period is usually of a few days duration, not less than two or more than twelve days. The duration of infectiveness is from six to eight weeks, extending throughout the whole period of illness. It is doubtful if one attack is protective or not.

An affection of the throat in many respects similar to human diphtheria, has been noticed as occurring in cats, pigeons, fowls, and other animals, during periods of epidemic prevalence of this disease. It is quite possible that the domestic animals, which live in close association with human beings, may in this way be a means of propagating the disease.

The supposed specific microbe of diphtheria, and the chemical products of its activity in the tissues, have been already alluded to (p. 376).

Asiatic Cholera.

Cholera is endemic in the delta of the Ganges, and probably also in other parts of India and the Orient. Epidemic extensions take place from time to time, the disease being imported from these "homes of cholera" into far distant countries, by sea or overland, by means of persons suffering from or recovering from it, or possibly by means of infected articles.

The usual mode of propagation of cholera is through drinking water. The specific poison is contained in the copious bowel discharges of the sick, and may find its way through the soil on which the dejecta are thrown into streams, wells, or tanks. It is also possible that the contagion is at times transmitted through the air, either by the dried choleraic discharges being borne into the air by currents of wind, or by emanations from the ground air of a soil soaked with the specific evacuations. Temperature and moisture are controlling factors of great importance. When the disease is imported into a temperate climate, the intensity of the epidemic is invariably felt in the late summer and autumn, and dies away with the approach of cold weather, possibly to again acquire epidemic intensity in the following summer. It is evident, therefore, that the specific virus can only attain its true virulence where the temperature of the air and, therefore, of the soil is sufficient. The combination of moisture and heat of soil characteristic of the Ganges delta, appears to offer the most suitable environment for the cholera virus.

Koch's comma bacillus has now been found in the typical rice-water evacuations of many cases of Asiatic cholera. The bacillus presents certain features, when cultivated in nutrient media, which serve to distinguish it from all other allied organisms; and a pure cultivation inserted into the ileum of a guinea-pig, which had been rendered torpid with loss of peristalsis by injection of opium, has produced symptoms of a choleraic nature. The bacillus does not develop spores, and is destroyed by drying and chemical disinfectants. It may be regarded as pathognomonic of the disease; and its presence when detected in the stools may be considered as sufficient to establish the diagnosis of Asiatic cholera—a result of Koch's labours of the very highest practical importance, as it will now be possible to make a diagnosis of sporadic or doubtful cases imported into a cholera-free country, and thus prevent at the outset the introduction of the poison.

Dr. Lauder Brunton has pointed out that the symptoms of cholera very much resemble those of muscarine poisoning; and recent research tends to show that these symptoms are due to the action of a chemical poison which may act independently of the microbes (comma bacilli) which produce it.

The incubation period of cholera is usually very short—one or two days; but it may occasionally be prolonged to ten days or more. The evacuations are most infective during the height of the disease; and it is believed that the specific virus (bacilli) may multiply, after leaving the body, in water or soil of suitable temperature.

In epidemic periods the proportion of deaths to attacks is greatest during the period of maximum intensity of the epidemic. When the epidemic is first commencing, and after it has begun to subside, the recoveries may considerably exceed the deaths in number. During the height of the epidemic the proportion of deaths to attacks is very much greater.

Enteric Fever.

Typhoid or enteric fever, excepting its possible origin from a cow disease, is a specific disease dependent for its propagation upon a specific virus. It is not always possible to establish the dependence of an outbreak on a pre-existing case; but it is not necessary for this reason to assume that the disease can originate independently—from decomposition of organic filth apart from the infection of a previous case—seeing that the contagion may undoubtedly have a long period of latency with diminution or loss of virulence, which can again be roused into action under special but unknown combinations of circumstances. Besides this, enteric fever is often a mild disease and unrecognised by the patient himself, who goes about his ordinary avocations unaware that he is spreading contagion broadcast.

The period of incubation is usually a long one, from 14 to 21 days, but the limits as to its duration are not accurately known. The infection is contained in the stools during the whole period of illness (4 to 8 weeks or longer); and the virus, which may possibly be the bacillus isolated by Klebs and other observers, is transmitted from the sick to the healthy, chiefly by means of drinking water, but occasionally through the air. In enteric fever, as in cholera, it would appear probable, that at the moment of leaving the body the specific contagion is not possessed of its greatest degree of virulence, but that outside the body the virulence increases as the microbe (if such it be) finds conditions of environment suitable for its growth and multiplication. Otherwise, these diseases would be far oftener transmitted to the nurses and attendants on the sick, and to sufferers from other diseases in the same hospital wards, than is the case in clean and well-regulated establishments.

Enteric fever is not a disease of universal occurrence like small-pox in unprotected communities. Many people appear to be insusceptible to the infection; but of this a partial explanation is offered by the possibility that the disease may have been contracted in childhood, when it is often mild and unrecognisable, and that, as a rule, one attack confers immunity for the remainder of life. No age and neither sex are free from risk of attack, but the period of 15 to 25 years appears to be specially prone to suffer.

During the period 1871-80, the mortality from enteric fever in England and Wales was at the rate of 0·32 per 1000 living at all ages; but the death-rate from this disease has undergone for a long period, and is still undergoing, a steady and sensible diminution year by year. In 1869 (the first year in which enteric fever returns, as separate from "fever," are obtainable) the death-rate was 0·39 per 1000; whilst in 1887 and 1888 the death-rate was only 0·18 per 1000, a reduction of more than half. The average death-rate for the 8 years 1881-8 was 0·2 per 1000. This result may be attributed to the improvements in water-supply, sewerage, and domestic sanitary arrangements throughout the country generally, that have been so marked a feature in the social progress of the latter half of this century.

The proportion of deaths to attacks in enteric fever cannot be accurately stated, owing to the number of mild cases that escape recognition. In typical cases the mortality varies from 15 to 25 per cent. of the attacks. In early life the type of the disease is less severe than in adolescence and adult age.

Enteric fever is most prevalent and causes the largest number of deaths in the late autumn. The seasonal curve (see p. 384, fig. 69) founded on the weekly deaths expressed as a percentage of the average weekly deaths in a year, is seen to rise in August and attain its maximum late in October or early in November, from which point it gradually falls. In our large towns a hot and dry summer tends to aggravate the intensity of the autumnal rise; and this fact, together with its special seasonal prevalence, appear to point to a high temperature being necessary for the proper development of the specific poison in stagnant sewer deposits or polluted subsoils, and for the attainment of its greatest degree of virulence. It must be remembered that the earth at a few feet from the surface heats much less rapidly than the air, and that the highest annual temperature in the soil is not attained until late in the summer or early in autumn.

Dysentery and Diarrhœa.

Diarrhœa is of course merely a symptom of very many diseases. But in the sense here understood, it means those acute attacks of illness of which the diarrhœa is the most prominent symptom, which occur so frequently in persons of all ages, but more especially in infants and young children towards the middle or close of a hot dry summer. The diarrhœa is in many cases of a choleraic nature accompanied by cramps, spasms, and signs of collapse, and appears to be due to the consumption of tainted food, or of impure water, or to the breathing of fouled air. The putrefactive changes which occur in food and fouled water or soil, are all more rapid and intense under the influence of a high temperature; and it is quite reasonable to believe that these diarrhœal attacks are due to the action of the bacterial agents of putrefaction, or of their products, when taken into the system. Recent research on this subject also tends to support such a view (see p. 409).

Dysentery arises in a very similar way, and is, no doubt, merely an accentuated form of the disease with a tendency to become chronic, incidental to a tropical climate. The effect of chilling of the body, on which so much stress has been laid, is probably to increase the susceptibility of the system to the entrance of the poison from without. Attacks of dysenteric diarrhœa with discharges of blood and mucus *per rectum*, are occasionally associated with outbreaks of diarrhœa in this country.

Although it is unquestionable that dysentery and acute diarrhœa in the vast majority of cases appear to arise *de novo*, independently of the contagion of a previous case, yet it is also as certain that the diarrhœal evacuations help to spread the disease in certain cases. It is not impossible that the diseased process may originate a specific poison within the body, which on evacuation has an infective virulence not inferior to the enteric fever or cholera poison.

From the seasonal curve for diarrhœa (fig. 72) it will be seen that the mortality begins to increase about the middle of June, rises rapidly to its maximum at the end of July or early in August, and falls somewhat less rapidly throughout August, September, and October.

A most exhaustive and excellent report by Dr. Ballard upon the "Causation of the annual mortality from diarrhœa, which is observed principally in the summer season of the year" has been recently issued.* The following is a very brief epitome of Dr. Ballard's observations.

The summer rise of diarrhœal mortality in the large towns does not commence until the mean temperature

* Supplement to Report of Medical Officer of the Local Government Board for 1887.

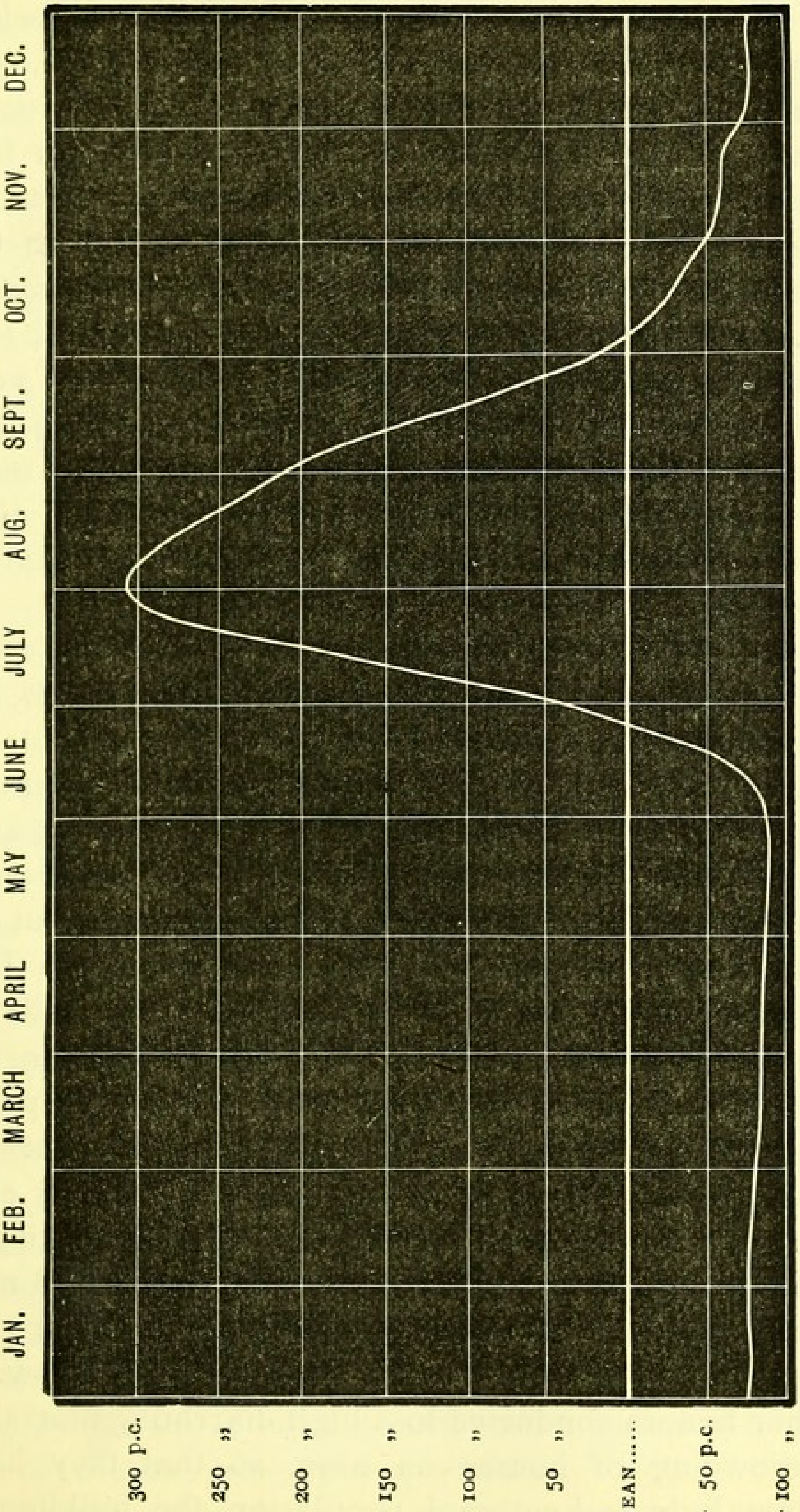

FIG. 72.—Curve of Diarrhœa Mortality (after Buchan and Mitchell).

recorded by the earth thermometer, placed 4 feet below the surface, has attained somewhere about 56° F.—no matter what may have been the temperature previously attained by the atmosphere, or recorded by the 1-foot earth thermometer. The maximum diarrhœa mortality of the year is usually observed in the week when the 4-foot earth thermometer attains its mean weekly maximum. The diarrhœa mortality declines with the 4-foot earth thermometer; and this decline takes place very much more slowly than that of the atmospheric temperature or of the 1-foot earth thermometer, so that the mortality from epidemic diarrhœa may continue long after the air temperature has fallen, even into the 4th quarter of the year.

The soils most favourable to a high diarrhœa mortality are those of sand, gravel, or marl, in which the constituent particles are small but freely permeable by air and water, and which contain organic matters of animal origin from "made ground," from manured surfaces, or from soakage of excretal refuse from privies, cesspools, and sewers. The soil must be moist, but the moisture must not be sufficient to preclude the free admission of air between the interstices, *e.g.*, soils in which the subsoil water stands sufficiently near the surface to maintain by capillary attraction the dampness brought about by previously greater nearness of the water to the surface, or marly soils containing clay sufficient to imprison enough of the water saturating it at some time previously. The moisture of the soil may arise from surface water sinking into the earth around houses, as well as from the subsoil water from below.

Other factors conducive to a high diarrhœa mortality are crowding of houses on area, so that they have deficient light and external ventilation, the building of houses back-to-back, and the keeping of milk and other foods in underground cellars exposed to telluric emanations, or in pantries liable to the entry of drain or sewer air.

As previously stated, the disease is mainly one of early childhood (0-5 years), but its incidence is by far the greatest on hand-fed infants. The attacks are usually extremely sudden in their onset; and that diarrhœa is merely one symptom or feature of the illness, is shown by the fact that many of the organs of those who have succumbed are found to be highly degenerated, more especially the kidneys, the liver (fatty degeneration), and the spleen. The lungs too are often the seat of pneumonic inflammation. Dr. Klein has failed to find anything in the tissues, blood, or excreta of these cases, to indicate that the malady is due to a microbe developing within the alimentary canal or permeating any of the tissues. But in certain groups of cases of epidemic diarrhœa, the disease is apparently communicable from person to person by means of the exhalations from the stools, and Dr. Ballard believes that in the excretions of such cases a specific micro-organism may possibly be found.

The following provisional explanation of the occurrence of epidemic diarrhœa is offered by Dr. Ballard:—

"That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism, not yet detected, captured, or isolated.

That the vital manifestations of such organism are dependent, among other things, perhaps principally upon conditions of season, and on the presence of dead organic matter, which is its pabulum.

That, on occasion, such micro-organism is capable of getting abroad from its primary habitat, the earth, and having become air-borne, obtains opportunity for fastening on non-living organic material, and of using such organic material both as nidus and as pabulum in undergoing various phases in its life history.

That in food, inside of, as well as outside of the human body, such micro-organism finds, especially at certain seasons, nidus and pabulum convenient for its development, multiplication, or evolution.

That from food, as also from the contained organic matter of particular soils, such micro-organisms can manufacture, by the chemical changes wrought therein through certain of their life processes, a substance which is a *virulent chemical poison.**

That this chemical substance is, in the human body, the material cause of epidemic diarrhœa."

During the decennium 1871-80, the death-rate in England and Wales from diarrhœal diseases was 0·93 per 1000 living at all ages. Under 5 years of age, the death-rate was 5·7 per 1000; and although this high rate is largely contributed to by the improper nourishment and feeding of infants, there can be no doubt that insanitary conditions, of the kinds named above, play a large part in its production. For the 8 years 1881-8, the average death-rate in England from diarrhœal diseases was 0·76 per 1000 living at all ages.

Rabies.

Rabies is a specific disease of which the virus—probably a microbe—has not been known to be transmitted otherwise than by inoculation, *i.e.*, by the bites of rabid

* Probably one of the alkaloidal Ptomaïnes.

animals. The virus, therefore, may be considered to be capable of undergoing multiplication only in the animal body, and to suffer complete loss of virulence when cast off from the body. It is certainly rendered inert by exposure to drying and extremes of temperature. All animals are susceptible to rabies, and the virus is always present in the saliva of rabid animals; during its development in the wolf and cat it appears to acquire specially virulent qualities.

Whilst in man the usual period of incubation after the infliction of a bite by a rabid dog is somewhere about 6 weeks, it may be as short as 6 days or as long as 2 years (Horsley). The rabic virus is chiefly contained in the nervous centres, and it is presumed that the disease only shows itself when these centres are attacked by the virus. This view explains the unequal length of the incubation period in different cases—the incubation period being governed by the time taken by the virus to travel from the point of inoculation up to the central nervous system, and for its development therein. If the virus travels up the nerves the incubation is long, but if conveyed in the blood stream the incubation may be very short.

In man, rabies or hydrophobia is now recognised as assuming two forms, (1) a mainly explosive one, characterised by convulsions and the symptoms usually recognised as hydrophobic; (2) a mainly paralytic form, unattended by the frightful sufferings of the first form, but far less common (Horsley). The same observer gives the death-rate among persons bitten by indubitably rabid dogs as on the average about 15 per cent.; that is to say about 85 per cent. of the persons bitten are insusceptible, or at least escape the action of the virus, for rabies once developed is almost invariably fatal.

M. Pasteur has elaborated a system of treatment by protective inoculations, which promises to render hydrophobia with its terrible sufferings a thing of the past. Shortly, it may be described as follows:—The spinal cord of a rabid rabbit, which like all parts of the central nervous system contains the virus, is submitted to a drying process at a temperature of 25° C., for a certain number of days (3 to 14). By this means the virulence of the virus (microbe) is destroyed, but waste products of its metabolism are obtained, which inhibit the growth of fresh rabies virus. The injection of this protective substance into the body of a person bitten by a rabid animal prevents the development of the rabies poison. That this is indeed the truth, is evident from the fact that persons who have been bitten by indubitably rabid animals, and have submitted themselves to the Pasteur treatment within a few days of the infliction of the bite, have almost invariably escaped. The death-rate, instead of 15 per cent. in the unprotected, is only 1·36 per cent. in the protected. For ordinary bites the inoculations start with the fourteen days dried cord and end with that of three days. For more dangerous wounds the number of inoculations is greater, and the use of the recent cords is more rapidly brought into operation. This is the "intensive" treatment, which is used in severe cases—bites on naked parts and wolf-bites. Nearly all the individuals treated by M. Pasteur, who have succumbed to the disease, developed it during the fortnight following the commencement of the inoculation, owing to the fact that in their case the virus probably passed in the blood stream to the nervous centres very soon after the infliction of the bite. (*Rabies*, by Victor Horsley, F.R.S., *Epid. Soc. Trans.*, 1889).

In this country rabies is spread by infected dogs; where muzzling regulations and the slaughter of stray dogs has been enforced, the disease is rapidly exterminated. These regulations have, so far, been very partially and locally enforced, with the result that rabies still lingers in some districts, from which it tends to spread into neighbouring localities as yet unaffected, or already freed from the disease by the preventive measures adopted.

Contagious Ophthalmia.

There are two kinds of contagious eye disease, the grey granulations (Trachoma) and purulent conjunctivitis; but the former also appears to predispose the sufferer to take the latter. These diseases are not uncommon in industrial schools and barracks, which are badly ventilated, and where the inmates are not supplied with separate basins and towels for ablution. They are chiefly transmitted from the sick to the healthy by inoculation of the eyes with the secretions and discharges left on linen and towels; but it is also probable that the contagion is carried through the air in dried epithelial or pus cells.

The ophthalmia caused by gonorrhœal infection of the eyes, and the *ophthalmia neonatorum*, inoculated from purulent vaginal discharge, are especially virulent and destructive forms of eye disease. In all forms of purulent ophthalmia a pyogenic micro-organism is probably the active cause of the disease.

The Prevention of Communicable Diseases.

In the olden times epidemical diseases were either regarded as the result of witch-craft or as visitations from the Almighty, according as the mind of the observer was philosophically inclined to look to all human events as the result of the interposition of an omnipotent power working for the evil or for the good of the human race. Superstitions of this sort being very deeply seated, it is needless to say that, in a more or less modified form, they survive to the present day amongst the unlettered and uncultured.

A more exact knowledge of the causes of disease enables us to attribute contagious diseases, whether occurring epidemically or not, to the regular workings of natural laws in a definite and established order of sequence. Knowing the causes, it is not difficult to devise means to prevent the spread of contagious disease by, so to speak, throwing out of gear the natural sequence of events in their propagation.

In the first place the *susceptibility of the individual may be modified*—(1) by protective inoculations which inhibit the growth of the specific organism, should it at any time gain an entrance into the body. At the present time protective inoculations of this description are only feasible in the case of small-pox, rabies, and anthrax. In the not remote future it may be expected that such inoculations will become possible for all the contagious diseases. But whether it will be desirable that such a practice should become general, must necessarily depend upon the risks to health or life attaching to it, upon the chance of suffering from the disease in point to which the individual is exposed, and upon its severity when contracted. The practice of vaccination is sound, because small-pox is a disease of universal occurrence from which few unvaccinated persons can hope to escape, and is especially fatal and severe in its effects. But no one would think of being inoculated for diseases of such rare occurrence as anthrax or rabies.

(2) The susceptibility of the individual to tubercle and possibly other diseases (erysipelas, epidemic pneumonia, diphtheria, hospitalism, ophthalmia) may be decreased by all those measures which are concerned in the promotion of the public health—by good drainage, by pure air, by pure water, by sufficiency and wholesomeness of food, and by unpolluted soils.

Such measures may be regarded as actually preventive of malaria, yellow fever, cholera, enteric fever, dysentery and diarrhœa; and they are most effective in modifying the severity of the specific eruptive fevers, although they only indirectly affect their occurrence and propagation.

In regard to this last class, which occur for the most part in regularly recurring epidemics, it is of the greatest importance that the epidemic should be stamped out at the first onset before the infection has had time to become widely spread. This can only be attained by a system of *compulsory notification* of all infectious diseases to the sanitary authority of the district. It will then be possible to isolate the first case or cases of the disease as they occur, to destroy the infection already generated, and to control the movements of the individuals with whom the sick persons may have come into contact. Without compulsory notification, it must almost necessarily happen that the disease obtains head-way before it is recognised, and then the most persevering efforts too often fail to obtain such a control as will prevent its wide-spread dissemination.

The *isolation* of all cases of contagious disease must be regarded as a most desirable measure, but is absolutely indispensable in the case of the epidemic diseases with air-borne contagia, if it is hoped to limit their spread. The same applies to the septic contagious diseases of hospitals. Diseases of the enteric fever class and tubercular diseases are rarely isolated, but it is probable that such a measure would have a considerable effect in limiting their spread. The more usually inoculable diseases—with the exceptions of leprosy, where segregation of the sick should be rigidly enforced, and of contagious ophthalmia—do not seem to demand measures of isolation.

To prevent the importation of a disease into an unaffected country by *quarantine*—most usually resorted to to exclude Asiatic cholera, yellow fever, plague, or other oriental diseases--is not in this country regarded as useful or practicable. The interference with commerce and national intercourse, the horrors to which the detained persons are exposed in quarantine camps or on board-ship with fever or cholera raging during their period of seclusion, and the uncertainty attaching to the period of incubation and its maximum duration in these diseases, are all reasons why the enforcement of rigid quarantine has given way to the more humane and rational system of isolation of the sick as soon as they arrive on the frontier or (in our case) seaboard, and of disinfection of the infected articles and of the whole ship, with observation of the movements of all the persons who leave the ship for a period of a fortnight or longer.

The isolation of the sick should invariably be enforced in cases of small-pox, typhus, scarlet-fever, diphtheria, measles, whooping-cough, etc., and this can most thoroughly be carried out by the removal of the patient to an infectious disease hospital. A difficulty arises in the case of measles, that the pre-eruptive stage is infectious, and that before the isolation can be effected, other persons have probably caught the infection. In measles and whooping-cough also, the contagion is so diffusible and universal that few can hope to escape; and the tender age of the sufferers in these and other infantile complaints renders them less suitable for hospital treatment than is the case with older children and adults.

Where removal to hospital is not feasible, isolation must be attempted by placing the patient in a room by himself at the top of the house, all communication with the other inmates being forbidden; and the aerial connection between the sick-room and the rest of the house must be broken by hanging up outside the door a sheet kept constantly soaked with some disinfectant liquid. Nothing must be allowed to pass out of the sick-room unless previously disinfected, and all dressings, poultices, and rags should be immediately burnt after use.

Disinfection.—As already mentioned, the virus of a contagious disease undergoes enormous multiplication in the body of the sick person, and is cast off during the period of illness in the discharges and secretions, in the breath and from the skin. The contagion infects the air around the patient, and infects the clothes and furniture of the sick-room. Disinfection aims at the destruction of the virus in these various situations.

In the first place it would be natural to suppose that the infective particles might be destroyed before leaving the body, or as soon as they are carried into the air.

But except in the case of scarlet-fever, where inunctions of carbolised oil to the surface of the body may prevent the desquamating skin acting as a source of infection, it is evident that chemical reagents strong enough to destroy specific micro-organisms would cause injury when taken into the system, or when diffused into the air around the patient. Where the virus is only contained in the evacuations, as in enteric fever, these can be at once disinfected by chemical solutions; but in the case of the other common infectious maladies, it is no use to attempt disinfection until the patient is convalescent and no longer a source of infection himself.

At the close of a case of infectious disease it becomes then necessary to disinfect the clothing, bedding, and linen of the sick person, and the furniture, the surfaces of walls, floors, and ceilings of the sick-room. Articles of little value such as toys, newspapers, and cheap books should be burnt.

Washable articles, *e.g.*, linen, cotton, and flannel garments should be steeped in cold water in the sick-room to remove the grosser impurities, and then placed in *boiling water* for 5 or 10 minutes before being sent to the laundry. Although a liquid cannot be absolutely sterilised by one boiling (see p. 59), yet it has been found experimentally that anthrax bacilli containing spores, are destroyed by a very few minutes boiling; for guinea-pigs are not affected by inoculation of a boiled cultivation. The anthrax spores are well known to be some of the most resistent and imperishable forms of bacterial life. Practically also, the singular protection against infection conferred by the boiling of milk or water, may be reckoned upon as a proof of boiling water being an efficient germicide.

Bedding (mattresses, pillows, palliasses), blankets, carpets, curtains, and cloth clothes, which cannot be submitted to boiling, must be disinfected by *dry heat* or *steam* in a disinfecting apparatus.

From Dr. Parson's experiments* it appears that steam is in many ways preferable to dry heat. It is a more powerful germicide; thus, spores of bacillus anthracis required for destruction four hours' exposure to dry heat of 220° F., or one hour's exposure to dry heat of 245° F., but were destroyed by 5 minutes' exposure to a heat of 212° F. in steam or boiling water. Other infective materials experimented on, viz., bacillus anthracis, bacillus of swine fever (infectious pneumo-enteritis), and tubercular bacilli, were destroyed by an hour's exposure to dry heat at 220° F., or 5 minutes' exposure to steam at 212° F.

Steam penetrates into bulky and badly conducting articles, such as mattresses, pillows, and clothing, far more rapidly than dry heat. As steam penetrates into the interstices of a cold body it undergoes condensation, and imparts its latent heat to the cold objects in contact with it. When thus condensed into water, it occupies only a very small fraction (about $\frac{1}{1300}$) of its former volume. To fill the vacuum thus formed more steam presses forward, in its turn yielding up its latent heat and becoming condensed, and so on until the whole mass has been penetrated. On the other hand, hot air in yielding up its heat undergoes contraction in volume, but only to a very small extent as compared with that undergone by steam in condensing to water. Thus, air at 250° F. in cooling to 50° F. would only contract to $\frac{5}{7}$ of its previous volume.

This penetrative property of steam may be increased

* Report on Disinfection by Heat. *Report of Med. Off. Loc. Gov. Board*, 1884.

by employing it under pressure, or by super-heating it, *i.e.*, by raising the temperature of the steam vapour without converting more water into steam, thus obtaining "dry" steam; and the pressure may be relaxed from time to time, so as to displace the cold air in the interstices of the material to be disinfected. With hot dry air the penetration of heat is aided by the admixture of steam.

The deficient penetration of dry heat is the great drawback to its use. Although a dry heat of from 220° F. to 250° F., continued for an hour, is almost certainly destructive of the viri of all human infectious diseases, yet as the heat penetrates so slowly, the interior of thick pillows and mattresses may, in an hour, not reach a temperature within 100° F. of the temperature of the air of the oven, and such articles when withdrawn are not thoroughly disinfected.

Washington Lyon's steam disinfector consists of a strong iron cylinder or chamber, elliptical in section, with double walls of boiler plate, and a door at each end. Steam is supplied from a boiler to the interior of the chamber and to the outer casing, at will. The outer casing should first be heated by steam, in order that the steam admitted into the chamber may not condense and moisten the articles to be disinfected. The pressure of steam and the temperature in the chamber can be read off by means of gauges and thermometers. To obtain a temperature of 250° F., a pressure of about two atmospheres must be employed; whilst by employing a higher pressure of steam on the outer casing than on the interior of the chamber, the steam in the latter can be super-heated, *i.e.*, made to attain a higher temperature than that corresponding to its pressure.

With this apparatus, as in all used in town disinfecting stations, the two doors of the chamber should open into two separate rooms; one—the infected side—used for the reception of the articles to be disinfected, whilst the other—the clean side—is used to receive them purified from the disinfecting apparatus. There must of course be no communication between these two compartments.

In Dr. Ransom's apparatus, heated air with the products of combustion of a gas furnace pass through the chamber. It consists of a cubical iron chamber cased in wood with an intervening layer of felt, with double doors at each end. The furnace is placed at the side of the chamber and on a lower level. It consists of a ring of atmospheric gas burners enclosed in an iron tube. The heated air containing the products of combustion passes along a horizontal flue and enters the chamber at the bottom, which is perforated by a number of holes for its equable distribution. In the horizontal flue are fixed the bulbs of a thermometer and of a self-acting mercurial regulator. Through the latter the gas supply to the burners can be made to pass, and it is so constructed that as the temperature of the apparatus rises, the mercury expanding encroaches upon a slit through which the gas passes, and thus gradually cuts off the supply. At the top of the chamber there is an outlet flue controlled by a valve and furnished with a thermometer. In connection with this outlet is an arrangement designed for the extinction of the gas should the clothing, etc., take fire: when the temperature at the outlet exceeds 300° F., a link of fusible metal melts, closing a damper and shutting off the supply of gas (Dr. Parson's Report).

In this apparatus the chamber is heated by currents of hot air, and Dr. Parsons found that in an apparatus of this form the distribution of temperature throughout the chamber is far more uniform than where the interior is heated by radiant heat, *i.e.*, by the direct application of heat from burning coal or gas to the floor or sides of the chamber. In the latter class also, the walls of the chamber become intensely heated, and if the articles of clothing come into contact with the hot metal they are very liable to be scorched or burnt. In Ransom's stove and in other stoves of the class where the chamber is heated by air warmed before its entrance, the walls of the chamber are no hotter than the air.

The temperature, whether with moist or dry heat, should never exceed 250° F., otherwise scorching occurs; and even this temperature is too high for white woollen articles. A temperature of 212° F. and upwards, whether dry or moist, fixes stains in fabrics, so that they will not wash out, especially where the stain is caused by albuminous materials coagulable by heat, such as blood. Where it is desired to remove stains, the articles must be steeped in cold water, before exposure to heat. Steam disinfection causes a certain amount of shrinkage in textile materials, and is inapplicable in the case of leather. Alterations in colour and gloss of dyed articles, and overdrying rendering the materials brittle, may also be the result of exposure to heat (*loc. cit.*).

Body lice and their eggs are destroyed by exposure to steam at 212° F. for 10 minutes, or to boiling water for 5 minutes. It is probable that a period of exposure not far short of 1 hour in dry hot air at 230° F. is necessary for their destruction.

The bedding, clothing, and other removable paraphernalia of the sick room being disinfected by boiling water, by dry heat, or by steam, it now becomes necessary to disinfect the sick room itself, its furniture, floor, walls, and ceiling.

In the first place the room should be as far as possible hermetically sealed—the windows closed and chinks pasted over with paper, the chimney outlet closed up, and the door crevices carefully filled in or pasted over. Some one of the *gaseous air purifiers* should then be evolved in the centre of the apartment for from 3 to 6 hours. *Sulphurous acid*, produced by burning sulphur in an iron vessel with a little spirit, is the most commonly used agent. As usually stated, the quantity to be employed should be 1 pound of sulphur to every 1000 cubic feet of the room. As 1 pound of sulphur in burning produces 11·7 cubic feet of SO_2, each 1000 cubic feet of air will contain 1·17 per cent. of the gas; but it is doubtful whether for efficient disinfection the percentage of the gas in the air should not be considerably greater. Sulphurous acid decomposes sulphuretted hydrogen and combines with ammonia, and is supposed to act powerfully upon organic matters.

Instead of sulphurous acid, one of the following gases may be used.

Ozone may be generated by gradually mixing 3 parts of strong sulphuric acid with 2 parts of permanganate of potash. Ozone is a powerful oxidiser and destroyer of organic matter.

Chlorine is best generated by gently heating a mixture of 4 parts of common salt (NaCl) and 1 part of manganese binoxide (MnO_2) with dilute sulphuric acid (half acid and half water). *Euchlorine* is a mixture of chlorous acid and free chlorine, and can be obtained by very gently heating a mixture of strong hydrochloric acid and potassium chlorate ($KClO_3$). Chlorine is a powerful bleaching and oxidising agent in the presence of moisture, combining with hydrogen and liberating oxygen. It rapidly decomposes sulphides of hydrogen and ammonium.

Nitrous acid is evolved from the action of dilute nitric acid upon copper filings. Nitrogen dioxide (NO) is given off and abstracts oxygen from the air, red fumes, a mixture of nitrogen tetroxide (NO_2) and nitrous acid (HNO_2), being formed. These gases are powerful oxidising agents giving up oxygen to oxidisable organic matters, and again combining with atmospheric oxygen.

Carbolic acid may be vaporised by applying heat to powders containing this substance.

Although all these substances are powerful deodorisers and effectually destroy offensive odours, the extent of their germicidal action, when mixed with air in the quantities usually employed in disinfection, is not known and may well be believed to be very slight.

After 6 hours of action of these gaseous substances, the apartment must be entered and the windows thrown wide open to allow of a free current of air passing through the room for at least 24 hours. The presence of fresh air and atmospheric oxygen is probably at least as efficacious as the action of the so-called gaseous disinfectants. The wall-papers should then be stripped off, the ceiling limewhited, and the floors, woodwork, and wooden or iron furniture well washed with soap and hot water, to which carbolic acid has been added in the proportion of 1 part of carbolic acid to 20 of water.

To disinfect enteric fever stools, tubercular sputa, and other discharges from the infectious sick, a large variety of chemical substances may be employed. Probably the most efficient of all is bichloride of mercury, a solution of 1 part in 1000 of water, being an active germicide—all the pathogenic organisms experimented on, with their spores, being destroyed after remaining in contact for a few minutes with a solution of this strength.

Carbolic acid (phenol) or cresol in 5 per cent. solutions are possibly equally efficacious. Other substances employed are chromic acid, bichromate of potassium, sulphate of copper, chloride of lime, perchloride of iron, potassium permanganate, chloride of zinc, etc.

Experiments have lately been largely conducted with these disinfectants, their action in a greater or less state of concentration being tried upon definite microbes such as bacterium termo, bacillus of anthrax (with or without spores), bacillus of tubercle, and bacillus of swine fever. The organisms experimented upon were subsequently submitted to cultivation in nutrient media, and from thence inoculated into susceptible animals, suitable control experiments being also conducted.

By such means it has been possible to define the degree of concentration necessary to constitute any one of these chemical substances a germicide. The results obtained tend to show that many powerful deodorisers are not germicides unless highly concentrated, although they may for a time render the organisms inert by inhibiting their growth and activity without actually destroying them.

The impossibility of disinfecting or sterilising large volumes of sewage or night-soil by the use of chemical reagents, unless applied in enormous and ruinous quantities, need hardly be insisted on. Small quantities of chemical reagents may be very efficient deodorisers, for offensive smells are easily concealed or destroyed; and by the ignorant the removal of offensiveness is regarded as equivalent to destruction of infection.

Hospitals.

The aggregation of a large number of sick persons suffering from a variety of diseases, or recovering from surgical operations, in one common building, is a necessity of modern life, but is now recognised as being attended with risks and dangers from which the patient treated in his own home is to a large extent exempt. In former times, this crowding together of the sick in hospitals led to outbreaks of erysipelas, pyæmia, and hospital gangrene in the surgical wards, the contagion appearing to be conveyed from one patient to another through the air, or by means of the surgeon's hands or instruments when engaged in dressing wounds. The antiseptic treatment of wounds and injuries, and the greater care bestowed on the construction and management of hospitals have nearly eradicated these terrible diseases from modern hospital practice; but when from any cause the surgical wards of hospitals are overcrowded, and the cleanliness and frequent dressings of wounds cannot be attended to, these septic diseases are almost sure to make their appearance and cause frightful havoc. Those who witnessed the horrible sufferings and mortality occasioned by dirt and overcrowding in the hospitals for sick and wounded during the Russo-Turkish war can bear evidence to the truth of this statement.

It has often been noticed that cases of open wounds, from injury or operation, recover far more rapidly when treated in the open air, or in huts and tents practically open to the air, than when confined in close buildings; and the same is true of cases of acute infectious disease. For such cases the breathing of pure air is a prophylactic worth more than all the drugs in the pharmacopœia. For the cases of organic disease of important viscera, which are treated in medical wards, the beneficial effects of pure air, though not equally striking, are not unimportant, although in these cases pure air and thorough ventilation must often be subordinated to considerations of warmth and moisture.

The first principle, then, in hospital construction and management is bound up in an abundant supply of pure air to the patients. The putrescent organic effluvia from the skins and lungs of sick persons, which, if not more copious, are certainly more deleterious than those from healthy people, must be diluted with fresh air and rapidly carried away. For each patient in a medical ward, the superficial floor space should not be less than 100 square feet, and the cubic space 1000 cubic feet. The air should be changed at least three times in an hour, which would give 3000 cubic feet of fresh air per head per hour. In wards containing many patients suffering from phthisis, bronchitis, or pneumonia, with much purulent expectoration, a higher set of figures should be taken.

For surgical wards and infectious disease hospitals the minimum floor space should be 140 square feet, and the minimum cubic space 1500 cubic feet per head, changed 3 or 4 times an hour. In the surgical wards, the effluvia from purulent or septic wounds are added to the exhalations from the lungs and skin, and require rapid dilution and removal. In the infectious wards, infective particles are wafted into the air from the skin and excretions, and must be destroyed by thorough oxidation as soon as formed.

For general hospitals it is found that the most convenient number of patients that may be treated in one ward, is on an average 30, this being the number which one nurse can readily supervise. In an *oblong ward* (fig. 73) with 30 patients, each patient to have 100 square feet of floor space and 1000 cubic feet of air space, 3000 square feet of floor space will be required and 30,000 cubic feet of air space. The 3000 square feet of floor space will be available if the ward is 120 feet long and 25 feet wide.

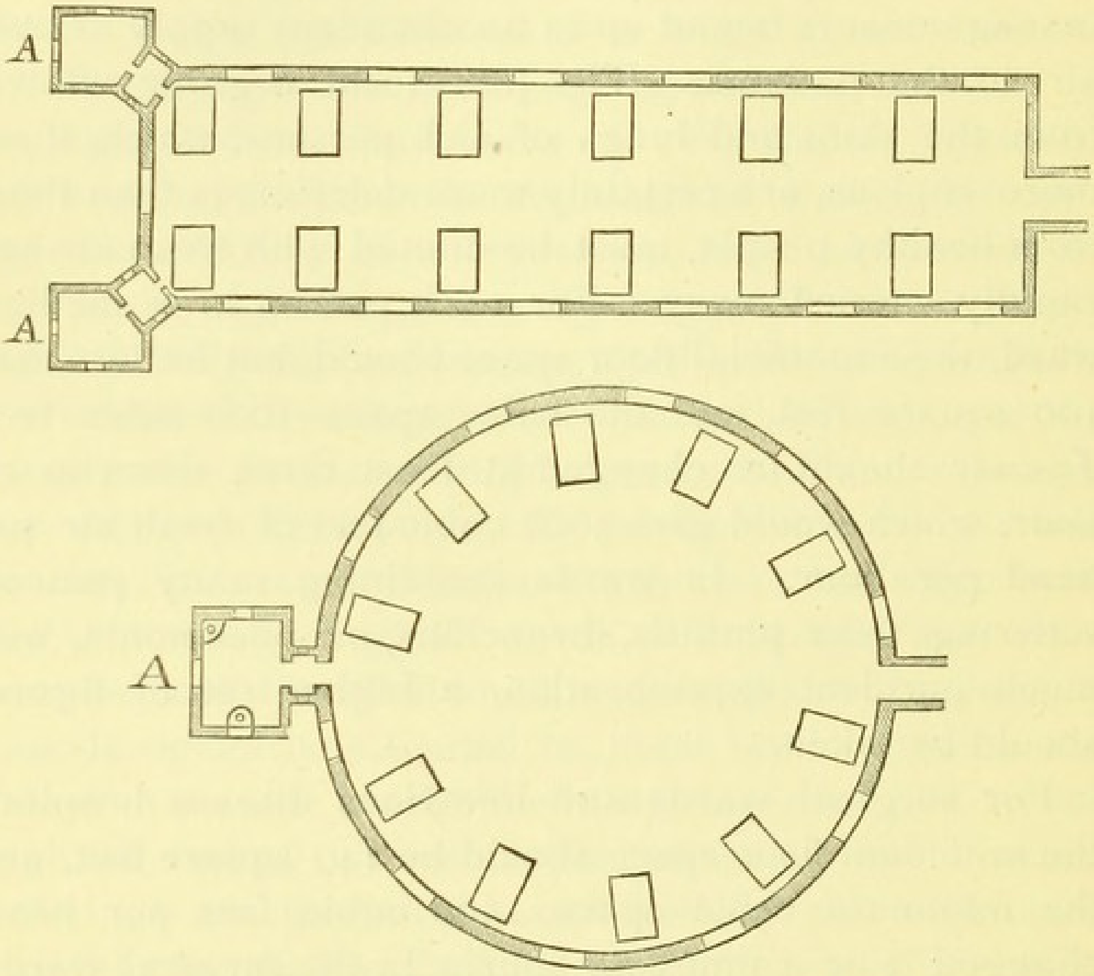

FIG. 73.—Diagrams of Oblong and Circular Wards. *A.* Turret Blocks for Water-closets, Baths, and Sinks.

As there are 15 beds on each side of the ward, the longitudinal wall space for each bed will be 8 feet, and the distance between any 2 beds (themselves 3 feet wide and 6½ feet long) will be 5 feet. The width of 25 feet is a convenient one, as it allows a passage 11 feet wide between the two rows of beds for the whole length of the ward, and permits of thorough cross-ventilation between the opposite windows, and the flooding of every part of the ward with daylight.

To provide the 30,000 cubic feet of air space the ward must be 10 feet high. It would be better to have the height of the ward 12 feet, which would allow 1200 cubic feet of air space per patient. Any height above 13 feet is useless for purposes of ventilation, and should be discounted in calculating the cubic space per head.

The *circular ward* system (fig. 73) has been much advocated. It has several advantages, such as the absence of corners for the accumulation of dust, the aspect facing all corners of the compass, by which the ward obtains sunlight at all seasons of the year and at every hour of the day, and the facility offered to nurses and attendants in passing from one bed to another. On the other hand if a circular ward is to accommodate the same number of patients as an oblong ward having an equal floor measurement and cubic contents, the beds of the patients, which are placed around the wall, must be very closely packed together, and the 8 feet of wall space per bed cannot by any possibility be attained.

Thus, for a circular ward to have 3000 square feet of floor space, the diameter of the circle must be 61·8 feet. The circumference of the circle will be 194 feet. From this must be deducted the width of the entrances of two lobbies or passages, say 13 feet, which leaves 181 feet of wall space for 30 beds or about 6 feet per bed, at the head of the bed. The circumference of the smaller circle formed by the feet of the beds is 153 feet, which gives 5 feet per bed at their feet, or an average of 5·5 feet for each bed. This means far too close approximation of the beds, and the creation of an evil not encountered in the oblong wards. There is a large open space in the centre of the ward unoccupied, which is of little use to the patients crowded together at the circumference. It has been proposed to utilise this space for a nurse's room or for a central staircase; but both these plans would create obstruction to cross-ventilation and access of light, whilst the central staircase might act as a shaft for the passage of foul air from one ward to another.

Where space will admit, the system of one-storied pavilions is far the best for all hospitals, and is especially suited for those intended for infectious diseases. The pavilions are connected with one another, and with the administrative blocks, by corridors which are, or may be, open to the air; and all risk of transference of foul air and effluvia from one ward to another is avoided. In large towns, a certain amount of crowding on a limited area is indispensable, and wards of two or more storeys in height must be built. Even in these, the system of disconnected pavilions should be aimed at, and the staircases require careful planning to prevent them acting as shafts for the passage of air from one ward to another. The external air space around the wards should be ample, and overshadowing by high buildings in the neighbourhood must be carefully avoided.

Provision should be made for the entrance of warmed fresh air in winter; this may be effected by Galton's ventilating open fireplace, or by a ventilating stove or stoves placed in the centre of the ward. Hot-water pipes should also be placed in the ward, as they may be required during very cold weather, or for the treatment of cases where much warmth is desired.

To secure the best kind of natural ventilation, the ward should have opposite windows reaching nearly to the ceiling, and the upper portion of each window should be made to revolve on its lower border into the ward, so as to admit fresh air during warm weather in an upward slanting direction. It is also very desirable to have a fresh air inlet close to the floor at the head of each bed, in order to ventilate the space under the bed, and at once carry away the respired air and effluvia from each patient. For the escape of the heated and vitiated air there should be numerous extraction shafts opening near the ceiling, which should unite together, the shaft being then carried up in close contact with the stove or chimney flue, in order that the column of air in it may not be allowed to cool and hinder the up draught. In summer, when the stoves are not in action, the same result may be produced by burning gas in Bunsen burners at the bottom of the extraction shafts.

The water-closets, bath-rooms, and slop-sinks, should be placed in a block outside the ward, but connected with it by a cross-ventilated lobby (fig. 73*A*). By this means, if disconnection of waste-pipes and ventilation of soil-pipes is properly attended to, there is no risk of foul drain air gaining access to the ward.

To exclude ground air from hospital wards is another very important measure; and this may be effected, as in ordinary buildings, by thoroughly concreting over the surface of the ground, and ventilating the space between the concrete and flooring through numerous air bricks, or by raising the ward some feet above the ground by arched vaults open on each side for their whole length for thorough ventilation.

Almost as important as good ventilation is the provision of internal surfaces (walls, floors, and ceilings) to the wards, which will not hold or absorb organic effluvia. The occurrence of erysipelas and surgical fever has been attributed—and probably rightly so—to wooden floors with chinks and crevices between the boards. The organic matters from poultices and dressings find their way into these crevices, and accumulate under the flooring. The floors are frequently washed, and the ascensional force of evaporation, when they are drying, carries up solid particles (organic débris and microbes), to be wafted into the air and spread disease from bed to bed.

The floors of the wards should be covered with oak parqueterie, or with solid wood-block flooring without chinks or cracks, laid on a bed of concrete. The surface should be painted or stained and varnished, and kept clean without washing. The parqueted floors should be oiled and beeswaxed. It is most essential to avoid washing floors with water. The air of the wards is by this means chilled from evaporation when the floor is drying, it becomes over-moist, and solid particles are wafted into it.

The wall surfaces should be impermeable. Glazed tiles set in Portland cement afford, perhaps, the best and most easily cleaned surface. But the walls may also be coated with cement or paint, or even distempered, if tiles are too costly. Ceilings may be cemented, or lime-washed several times a year.

The beds should be of iron with spring-wire mattresses, and in the surgical wards provided with movable fracture boards. It is very important to reduce the furniture of the ward to a minimum, and to allow no curtains, hangings, or drapery of any sort.

Excreta, sputa, dirty dressings, and poultices must be removed from the wards at very frequent intervals. In the case of infectious disease hospitals, it is very desirable that these refuse matters should be destroyed.

This can be done by means of a small destructor furnace in connection with the boiler-house or heating furnace of a large hospital. In small-pox hospitals, recent experience shows that even the air extracted from the wards should be purified by passage through a furnace before it escapes into the outer atmosphere. Without some such safeguard, small-pox hospitals are a centre of infection for the surrounding neighbourhood.

For the exercise of the patients, covered balconies on the southern or western aspects of the building should be provided; and in large towns where space for a garden is wanting, a flat roof affords a valuable exercise and recreation ground.

In some of the more recently constructed hospitals, it has been found convenient to place the kitchens and sculleries at the top of the building, and to use gas and steam for all culinary purposes.

Every town should have hospital accommodation for the isolation of cases of infectious disease. The amount of accommodation required will depend upon the character of the population; but it may be stated generally that there should be at least one bed to every 1000 of the population, when this is largely composed of the industrial classes. The one-storied pavilion system is most suitable for infectious disease hospitals, and one pavilion should be set aside for the separate accommodation of small-pox cases. A site should be chosen outside the town in a thinly populated neighbourhood.

In epidemic periods it may be necessary to supplement existing hospital accommodation, and for this purpose tents (in summer) or huts of galvanised iron, wood, Willesden water-proof material, or Dœcker's material (a water-proof composition resembling leather), can be erected. Huts of the three last materials are preferable to iron as they are easier to warm. The floors should be raised a foot from the ground, and the ridge of the roof should be used for ventilation as well as the windows. If these huts are constructed with hollow walls, the temperature in cold weather can be properly maintained with efficient ventilation—a difficult task without hollow walls, owing to thinness of the materials. As the wood and water-proof compositions used in the construction of these hut hospitals are liable to rot and decay, they can only be regarded as temporary structures; and as soon as the emergency which necessitated their erection is over, they are best pulled down and destroyed.

CHAPTER X.

STATISTICS.

Statistical Inquiries.

THE science of statistics consists in the collection of individual facts, with the view of grouping them into different classes according to certain definite characters they possess. For instance, a certain number of deaths are recorded in the course of a year: these are the individual facts. These deaths may be sub-divided into groups according to the ages or the sex of the deceased persons, or according to the nature of the disease which proved fatal to them, etc. The rule to which attention must be specially directed in differentiating a series of facts, is that the points of difference or characteristics on which a group is to be formed, should be common to each member of that group, but absent from the members of all other groups. The dividing character must be constant, and must be definite. The numerical relations between the series of facts in the group or subdivision, and the total number of cases which furnish the groups, are usually expressed as percentages, or multiples of percentages (per 1000, per 10,000, per 1,000,000), by multiplying the number of cases or units in the group by 100, 1000, etc., and dividing the result by the total number of cases.

It does not follow that because, in any series of cases, the groups bear a certain numerical proportion to the total number of cases, these proportions will be the same in any subsequent series of like cases, unless the numbers dealt with in the first case are infinitely large. The smaller the number of individual facts on which the groups are founded, the greater is the possible deviation from the proportions which may be observed in any subsequent series of like facts. By *Poisson's Rule* the limits of error, or the degree of approximation to the truth of the numerical relations existing between the units or groups of units of a series, may be ascertained.

Let M = total number of cases in the series recorded.
,, m = number of cases in one group.
,, n = number of cases in the other group.

Then $m + n = M$, and $\frac{m}{M}$ and $\frac{n}{M}$ are the proportions of each group to the whole. But on subsequent occasions, with another series of like cases, the proportions may be

$$\frac{m}{M} + 2\sqrt{\frac{2.m.n}{M^3}};\ \text{or}\ \frac{m}{M} - 2\sqrt{\frac{2.m.n.}{M^3}}.$$

And the same holds good with n group of cases. The larger the value of M, the less will be the value of the fraction of which M^3 is the denominator, and consequently the smaller the error to be added to or subtracted from $\frac{m}{M}$ or $\frac{n}{M}$.

Example.—M = 100 cases of fever.
m = 25 cases which die.
n = 75 cases which recover.

Then the proportion $\frac{m}{M}$ or $\frac{1}{4}$ may be in other instances

$$\tfrac{1}{4}+2\sqrt{\frac{2\times 25\times 75}{100^3}}=0{\cdot}25+0{\cdot}1225=0{\cdot}3725$$

$$\text{or}\ \tfrac{1}{4}-2\sqrt{\frac{2\times 25\times 75}{100^3}}=0{\cdot}1275.$$

That is to say, the number of deaths out of 100 other cases of the same fever, instead of being 25, may be as many as 37 or as few as 13. But if, instead of 100 cases of fever in the original series, there had been 10,000 cases, the limit of error would have been only 0·01225 in unity, or 1·225 per cent. above or below the proportion found actually to exist.

The average or arithmetical mean of a series of figures is obtained by adding together the numerical values of the figures, and dividing the total by the number of figures in the series. This average or mean number will have a higher numerical value than belongs to some of the figures composing the series, and a lower numerical value than belongs to others. The less the difference between the average and the figures of the series, the greater is its value. The relative values of two or more similar series are as the reciprocals of the squares of the probable errors; that is as $\frac{1}{(pe)^2}$, where *pe* is the probable error. The probable error is approximately two-thirds of the mean error which is obtained as follows:—1. Find the *mean* of the series of observations; find the *mean* of all the observations *above* the mean, and subtract the mean from it; this gives the mean error in excess. 2. Find the *mean* of all the observations *below* the mean, and subtract the latter from this mean; this gives the mean error in deficiency. Add the two quantites (mean error in excess and mean error in deficiency), and take the half; this is the *mean error*. (Parkes' *Practical Hygiene*, Footnote, p. 482).

The relative values of two or more series are also as the square roots of the number of units of observation. By increasing the number of observations in any inquiry, the value (or accuracy) increases as the square root of the number (*loc. cit.*).

Vital Statistics.

To obtain the statistics of a community which have relation to its public health, it is necessary to have a correct enumeration of the population, a complete registration of births and deaths, and in the case of deaths, a correct statement as to their cause, together with the age of every deceased person. The number of births and deaths which take place in the course of a year, are generally expressed in the form of birth-rates and death-rates, *i.e.*, so many births or so many deaths to 1000 of the population.

The first inquiry, therefore, which becomes necessary, is to ascertain for any community the number of the living during any year, or at any period of a year. The last census returns of the population give the necessary information—the exact enumeration of the numbers living and their ages at the time the census was taken. If the population is stationary—the births equalling the deaths and no emigration or immigration taking place—the census returns are true for any subsequent year. But there are few communities of persons, in this country at any rate, where the population is stationary for any length of time. It becomes then necessary to refer back to the last census but one, to ascertain if the population in the 10 years between the two enumerations, has increased, decreased, or remained stationary. In this country, the births have—for a great number of years—exceeded the deaths and the emigrations, with the result of a steady increase of population.

By the *Law of Population*, a population increases in regular geometrical progression when the births exceed the deaths, and the ratio of the births and of the deaths to the population remains constant. In England from 1801 to 1841, the mean rate of increase for each unit of the population was 0·0141 annually. The increase in any number of years (n) between 1801 and 1841 is derived from the increase in one year by multiplying 1 + the annual rate of increase (0·0141) n times into itself. Conversely to obtain the annual rate of increase from the increase in n years, the n^{th} root of the increase in n years must be taken.

Example.—If the birth-rate of a population numbering 5000 is 30 per 1000, and the death-rate is 20 per 1000, and these rates remain constant for 10 years, the annual rate of increase is 10 per 1000, or 0·01 per unit; *i.e.*, one person becomes 1·01 at the end of a year, or 1000 persons become 1010. The population at the end of the 10th year (the last term of the series in geometrical progression) $= 5000 \times 1{\cdot}01^{10} = 5523$ persons. For the population at the end of the first year is $5000 \times 1{\cdot}01$; at the end of the second year it is $5000 \times 1{\cdot}01^2$, and at the end of 10th year $5000 \times 1{\cdot}01^{10}$.

The proof that the population actually does increase in geometrical progression may be explained as follows:—If the population at the end of the first year becomes $5000 \times 1{\cdot}01$, the population at the end of the second year must become $5000 \times 1{\cdot}01^2$;

for $\dfrac{5000}{5000 \times 1{\cdot}01} = \dfrac{5000 \times 1{\cdot}01}{x}$; from which it follows that $x = 5000 \times 1{\cdot}01^2$; and so on for the remaining years.

The census is taken every 10 years, at the end of the first quarter of the year. In calculating birth-rates or death-rates for any year, the estimated population for the middle of that year must be taken as the basis; for it alone represents the average number of persons who are living in that year. The following method, devised by the Registrar-General, may conveniently be used for estimating the population of a town or district for the middle of any year from the two last census returns.

Example.—Suppose the population of a town by the census of 1871 is x, and by the census of 1881 is y, and it is required to know the population in the middle of the year 1888. Let r = annual rate of increase per unit of the population. Then $y = x \times (1 + r)^{10}$: and $10\ log.\ (1 + r) = log.\ y - log.\ x = log.$ of the rate of increase for 10 years. If $log.\ (1 + r)$ is denoted by $log.\ a$, then $\frac{log.\ a}{10}$ or $\frac{log.\ y - log.\ x}{10} = log.$ of the rate of increase for one year.

Therefore *log.* of population in middle of 1888

$$= log.\ y + 7 \times \frac{log.\ a}{10} + \frac{1}{4} \times \frac{log.\ a}{10}.$$

This formula assumes that the population of the town is increasing or decreasing in the same ratio since the last census, as it did between 1871 and 1881.

It is here that a fallacy may arise. The population which serves as the basis for calculating the birth and death-rates in the 9 years intervening between any two census returns, is only an estimate, and therefore only approximately true. The estimates of population so obtained generally exhibit a considerable divergence from the actual truth in the years most remote from the last census. Consequently statistics calculated upon such estimates are usually erroneous. A comparison may be made between this estimate and that arrived at by a calculation of the number of inhabited houses in the district, and the average number of inhabitants in each—but this again is only an approximation. Another means of checking the estimated population is by assuming that the birth-rate per 1000 inhabitants remains fairly constant in a series of years; and this assumption is found to hold good when applied to large populations. Then the population

$$= \frac{\text{registered births in the year} \times 1000}{\text{average birth-rate for previous 10 years.}}$$

It is, however, most desirable that the census should now be quinquennial instead of decennial.*

Birth-rates and death-rates may be calculated as annual rates to 1000 persons living, from weekly, monthly, or quarterly returns. They represent the number of births or deaths that would take place per 1000 of the population in a year, if the proportion of births and deaths to population, recorded in these shorter periods, were maintained throughout the year. Now the correct number of days in a natural year is 365·24226, and the correct number of weeks is 52·17747. The birth-rate or death-rate may be accurately calculated from weekly returns in the following manner.

Example: let b = number of births recorded for the week.
,, d = number of deaths recorded for the week.
,, x = population estimated to the middle of the year.

Then the birth-rate per 1000 $= \left\{ b \div \frac{x}{52{\cdot}17747} \right\} \times 1000.$

or what is the same thing,

$log.$ birth-rate per unit $= log.\ b + log.\ 52{\cdot}17747 - log.\ x.$
and $log.$ death-rate per unit $= log.\ d + log.\ 52{\cdot}17747 - log.\ x.$

The length of the calendar month varies from 28 to 31 days, and of the quarter from 90 to 92 days; so

* See paper by the Author on "Some Aspects of Mortality Statistics," *Public Health*, August, 1888.

that the birth-rate or death-rate from monthly or quarterly returns is obtained thus :—

Example : let x = number of days in the month.
,, y = number of days in the quarter.

Then birth-rate per unit $= \left\{ b \div \dfrac{\dfrac{\text{population}}{365{\cdot}24226}}{x} \right\}$, where b = births in a month.

Or birth-rate per unit $= \left\{ b \div \dfrac{\dfrac{\text{population}}{365{\cdot}24226}}{y} \right\}$, where b = births in a quarter.

In large towns a certain number of deaths occur in public institutions (hospitals, workhouses, etc.). In London, which is divided into a number of parishes, in calculating the death-rate of any parish, the deaths of inhabitants of other parishes, which occur in public institutions in those parishes, must be excluded; whilst deaths of parishioners occurring in the public institutions in the parish and outside it, must be included in order to arrive at the true death-rate. In London, the figures required for this purpose are now supplied to Medical Officers of Health by the Registrar-General. Formerly it was the custom to assign to each parish, out of the total deaths in public institutions in London, a number proportional to its population. This method served very well when the exact figures were not obtainable.

It may be well to point out in this place—especially as misunderstanding is constantly arising on the subject—what is the true significance of death-rates, and how far they are reliable as tests of the health and sanitary surroundings of different communities! The fallacies arising from a wrong estimate of population have been already alluded to.

Death-rates constructed from the mortality returns of short periods such as a week or month, are not reliable as tests of health. They are necessarily subject to accidental fluctuations, which must prevent any true conclusions being drawn from them. So, too, with the death-rates of very small populations, even when they exhibit returns covering a period of a year. The numbers, on which the figures are founded, are not sufficiently large to exclude those accidental fluctuations from varying circumstances, which must be got rid of before any just reasoning can be founded on death-rates. It is different with the death-rates from yearly returns of larger populations. Where the units, on which the figures are founded, are sufficiently large, accidental fluctuations are swamped—so to speak—and the errors traceable to them are reduced to very small limits, so that trustworthy results are obtained.

But in comparing death-rates of different towns or districts with each other, there are other sources of error which must be taken into account. A population consists of a number of people living at every age from the time of birth to 100 years or more. Now the age distribution of two or more populations may vary widely—the proportions of children, adults, and old people, to the total population in different cases being often very different. If the death-rate were the same for all ages, this different age-distribution might be neglected. But such is not the case; children under 5 and old people over 55 years of age die at a greater rate than the death-rate for all ages; whilst from the age of 5 up to 55, the death-rate is less than the general rate. There is another disturbing factor, and that is the proportionate number of males to females in any population. Females at all ages have lower death-rates than males.

The following table exhibits the death-rates at different age-periods (calculated upon the numbers living at each age-period) amongst males and females in England and Wales during the 10 years 1871-80.

Annual Mortality per 1000.

	MALES.	FEMALES.
All ages	22·61	20·00
Under 5 years	68·14	58·10
5-10 "	6·67	6·20
10-15 "	3·69	3·70
15-20 "	5·23	5·43
20-25 "	7·32	6·78
25-35 "	9·30	8·58
35-45 "	13·74	11·58
45-55 "	20·05	15·59
55-65 "	34·76	28·54
65-75 "	69·57	60·82
75 and upwards . . .	169·08	155·83

(Supplement to the 45th Annual Report of the Registrar General).

From these figures it will be seen that it would not be right to compare the general death-rates of two towns, one of which—let us suppose—had a larger proportion of females and of young adults, and a smaller proportion of males and old people, than the other. Corrections must be made for age and sex-distribution. It is for this reason that the uncorrected death-rates of rural districts overstate, whilst the death-rates of large cities understate the real mortality. For instance, the recorded average death-rate for Dorsetshire during the 10 years 1871-80 was 17·46 per 1000. If the age-distribution of Dorsetshire had been the same as for England

and Wales generally, the correct death-rate is 15·97 per 1000, or 1·5 per 1000 lower than the recorded rate. But the Lancashire death-rate when thus corrected is 26·87, instead of 25·17, or 1·7 per 1000 higher than the recorded rate.

In Dorsetshire the population is very sparse and scattered (3·27 acres to a person), whilst in Lancashire (0·41 acres to a person) with its many manufacturing towns in which the population is closely aggregated, the density of population is comparatively great. In many parts of large towns the density of population is very great—0·005 acres to a person, or less—and the death-rate correspondingly high. The high death-rates, which go with dense population, are not simply the result of aggregation. Aggregation means no doubt, generally, polluted air and possibly polluted water and soil, and the easy spread of infectious disease. But as Dr. Ogle has pointed out, the more crowded a community, the greater the amount of abject want, filth, crime, drunkenness, and other excesses, the more keen is the competition, and the more feverish and exhausting the conditions of life. It is, too, in these crowded communities that the most dangerous and unhealthy industries are carried on. These indirect consequences of aggregation influence the mortality greatly more than the direct.

Besides normal increase of population by excess of births over deaths, the immigration into large towns, which always greatly exceeds the emigration from them, tends to bring large numbers of young adults into the population, and so influence the age-distribution. The following table gives the age-distribution of 1000 persons in England and Wales (mean of censuses of 1871 and 1881).

All ages.	Under 5.	5-10	10-15	15-20	20-25	25-35	35-45	45-55	55-65	65-75	75 and upwards.
1000	136	120	107	97	89	147	113	86	59	33	13

The Registrar-General has adopted the following method for making the necessary corrections for age and sex-distribution in any population. (Annual Summary, 1883).

The mean annual death-rate for each sex, at each of the 12 age-periods in England and Wales in 1871-80, is applied to the population of the town or district under consideration with age and sex-distribution as shown at the last census (1881). The result is a number called the *standard rate*, which varies in every town or district according to the age and sex-distribution of the population of the town or district. The mean annual death-rate of England and Wales for 1871-80, viz. 21·27, is then divided by this standard rate, and a factor is obtained for the town or district, by which the recorded death-rate of any year must be multiplied. This factor exceeds unity in 26 out of the 28 large towns of the Registrar General, showing that their death-rates without correction are understated, and is less than unity in the remaining two towns, showing that in these two cases the uncorrected death-rates are overstated, when compared with the country generally.

We are now in a position to understand the influence of birth-rate upon death-rate. Some years ago Dr. Letheby asserted that a high death-rate was not necessarily an evil. "An increase in the rate of mortality is often a sign of prosperity, for a high death-rate means a high birth-rate, and a high birth-rate is the invariable concomitant of prosperity." It is true that in large towns high death-rates go with high birth-rates; but, as pointed out by the late Dr. Farr, high death-rates are not the result of high birth-rates, rather are they caused by density of population (overcrowding on space and in houses) and by bad sanitary conditions. High birth-rates should cause a lowered death-rate; for if year by year the births exceed the deaths amongst a population, not only are additional children under 5 years of age, whose mortality is high, added to the population, but a still larger increase of children and adults above that age, whose mortality is low, takes place; whilst the proportion of old people over 55 years of age to the total population is diminished. A high birth-rate, therefore, continuing over a period of years, is favourable to a low death-rate, and a low birth-rate to a high death-rate. If we find—as is actually the case—that a rural district with a low birth-rate has also a low death-rate, whilst an urban district with a high birth-rate has a high death-rate, we must conclude that the sanitary surroundings, the occupations, or the social conditions of the rural district are more favourable to life than those of the urban. These are the main causes of the varying health-conditions of populations, of which death-rates, with certain limitations, afford trustworthy evidence.

In estimating the total death-rate of a combination of two or more districts, which exhibit different mortality figures, it is necessary to add together a fraction of each death-rate—the fraction being the proportion represented by the population of each sub-district to the whole population of the combined districts. The method of taking the average of the district death-rates, irrespective of population, would introduce a serious error.

Example.—If A has a population of 10,000, and a death-rate of 25 per 1,000; if B has a population of 2,000 and a death-rate of 10 per 1,000; and if C has a population of 7,000 and a death-rate of 15 per 1000; the death-rate of the combined districts with a population of 19,000 is

$$\left(\frac{10,000}{19,000} \times 25\right) + \left(\frac{2,000}{19,000} \times 10\right) + \left(\frac{7,000}{19,000} \times 15\right) =$$

$$\left(\frac{10}{19} \times 25\right) + \left(\frac{2}{19} \times 10\right) + \left(\frac{7}{19} \times 15\right) =$$

$$\frac{250 + 20 + 105}{19} = \frac{375}{19} = 19{\cdot}7.$$

If, however, the average of 25, 10, and 15, had been taken, viz., 16·6, an error of 3·1 per 1,000 would have been committed.

The *mean age at death* of a population, is obtained by summing up the ages at which people die, and dividing the number of years by the number of deaths. It is merely an expression of the average age at death of a population, and gives no evidence of the health or sanitary condition of the community. When a population is rapidly increasing by excess of births over deaths, the mean age at death is low, because the population is largely composed of young persons. When a population is nearly stationary, the proportion of old people to the total population is large, and the mean age at death is high. The "mean age at death," therefore, gives information as to the ages of the dying and *per contra* of the living in different communities, but nothing more.

The *mean duration of life* or *expectation of life at birth* differs widely from the "mean age at death," when the population is increasing, although when the population is stationary, they coincide. Thus the mean duration of life in England (1871-80) for males was 41·35 years; if the population were stationary, the mean age of males who died would have been 41·35, and 1 in 41·35 would have died every year. Whereas the mean age at death was only 29 years, whilst 1 in 44·2 died annually. One in 44·2 died annually and not 1 in 41·35, because the increase of population has been so long continued by excess of births over deaths, that an excess of persons between the ages of 5 and 55 has accumulated, whose mortality is low; and this excess, together with proportional diminution of persons over 55 years of age, has served to reduce the death-rate. The mean duration of life is found from Life-Tables, which show how many of a given number born, live through each year of age, and what is the sum of the number of years they live; the sum of these years divided by the lives is the mean duration of life (mean after-lifetime or expectation of life at birth). It is not the same thing as the *probable duration of life*, which is the age at which a given number of children born at the same time are reduced one-half. The mean duration of life for males (English Life-Table, 1871-80) was 41·35 years, whilst the probable duration of life was about 47½ years.

Mean after-lifetime is a more accurate expression than expectation of life, as, strictly speaking, the time which it is expected a person will live, is the time which it is an even chance he will live; it is then strictly the probable duration of his life. It has been thought advisable to retain here the term "expectation of life," as being the term usually employed in life-tables. It must be understood, however, to mean, whenever expressed, the mean after-lifetime, and not the probable duration of life.

English Life-Table 1871-80 (abridged from Dr. Ogle's)*

Age.	Males.		Females.	
	Of a million born number surviving.	Mean after-lifetime.	Of a million born number surviving.	Mean after-life time.
0	1,000,000	41·35	1,000,000	44·62
1	841,417	48·05	871,266	50·14
2	790,201	50·14	820,480	52·22
3	763,737	50·86	793,359	52·99
4	746,587	51·01	775,427	53·20
5	734,068	50·87	762,622	53·08
10	708,990	47·60	738,382	49·76
15	696,419	43·41	724,956	45·63
20	680,033	39·40	707,949	41·66
25	657,077	35·68	684,858	37·98
30	630,038	32·10	658,418	34·41
35	598,860	28·64	628,842	30·90
40	563,077	25·30	596,113	27·46
45	522,374	22·07	560,174	24·06
50	476,980	18·93	520,901	20·68
55	424,677	15·95	477,440	17·33
60	365,011	13·14	422,835	14·24
65	297,156	10·55	356,165	11·42
70	222,056	8·27	277,225	8·95

It has been shown by the late Prof. De Chaumont that the mean duration of life may be approximately calculated from the birth-rate and death-rate by the following formula; where b = birth-rate per unit of the population; and d = death-rate per unit of the the population.

Then *mean duration of life* $= \left\{\frac{2}{3} \times \frac{1}{d}\right\} + \left\{\frac{1}{3} \times \frac{1}{b}\right\}$.

At other ages than at birth, the mean duration of life is often held to be the expectation of life at the age in question added to the present age.

* Supplement to the 45th Annual Report of the Registrar-General.

The latest English Life-Table (Dr. Ogle's) is based upon the mean population, of each sex, and at each year of age, of the decennium 1871-80, and on the total deaths for each sex at each year of age during the same period. Then the rate of mortality per unit of the male or female population at any age x =

$$\frac{\text{number dying at age } x}{\text{mean population at age } x} = m_x.$$

The mean population at the age x is the precise number returned as living at the age x less one-half of the deaths occurring in the ensuing year. The probability that a person of the precise age x will survive one full year $= \frac{\text{number of survivors at end of year } x}{\text{number living at beginning of year } x} = p_x$; and it has been ascertained that $p_x = \frac{2 - m_x}{2 + m_x}$.

Thus starting with a certain number (l) at birth, if l is multiplied by the probability of living one year, the number surviving at the end of the year is obtained. Similarly the number living at the end of the second year is obtained by multiplying the number commencing the year by the probability of their surviving the year, and so on. In this way, commencing with a certain number at birth, the number surviving at each year of age up to 100 or more years can be ascertained and entered in the Life-Table column (see *Vital Statistics*, by A. Newsholme, M.D.).

Life-Tables, besides giving the numbers surviving at all ages from a million born at one and the same time, also show what is the expectation of life (mean after-lifetime) at each year of age—that is the length of time a person of any age may be expected to live. The expectation of life at any age is derived from the numbers living at the age in question (given in the Life-Table) and from the years of life they subsequently live, just as is the mean duration of life (expectation of life at birth). For ages between 25 and 75, Willich's formula also gives approximate results.

If x = expectation of life, and a = present age, then $x = \frac{2}{3}(80 - a)$.

Life-tables afford an excellent test of the health of a community. By the English Table for 1871-80, the expectation of life at birth for males is 41·35 years. The expectation of life increases every year in both sexes up to the 4th year, when it is 51·01 for males, and 53·2 for females, the dangers to life of the period of infancy being then passed. Subsequent to the 4th year, the expectation of life gradually decreases for each year of age. The expectation of life for males at all ages up to 19 years, is higher by the recent Table—1871-80—than by the previous one—1838-54. But after the age of 19, the expectations of life are slightly higher by the old Table than by the new. For females the expectation of life is greater by the new Table up to the age of 45, and subsequent to that age is less than by the old Table.

The causes of this alteration in figures between the new and old Life-Tables, appear to be that by improved sanitary surroundings the lives of infants and children have been saved in the recent period which were sacrificed in the former, thus increasing the expectation of life during childhood and youth. After reaching adult age, males are now subjected to conditions which are not more favourable to life—probably less so from increased competition and difficulty in gaining a livelihood—than existed between 1838-54, and this, together with the fact that some of the lives saved in childhood are probably unhealthy ones, which would have perished under the old sanitary conditions, accounts for the expectation of life being now actually less for adults and old people than formerly. Females not being subject to the same conditions as males and living more at home, are likely to derive benefit from improved sanitation after reaching adult age, as is indeed plainly shown by the Life-Tables. After the age of 45, however, the unhealthy lives saved in infancy begin to influence the expectation of life.

Although by the male Life-Table the expectation of life after 19 years is less now than formerly, the numbers living at each year of age up to 68 years are greater by the 1871-80 Table than by the 1838-54 Table; after 68 the numbers living are less. By the female Life-Table the numbers living up to the age of 92 are greater by the new than by the old Table. So that there has been a great saving of life in recent years, not only of females, but of males also up to an age which embraces the most productive periods. Although, out of a given number of children born, more survive and reach an advanced age than formerly, it must not be thought that individual life is lengthened. As the Life-Tables show, individual life is shortened after reaching a certain age in both sexes, but the shortening takes place at a much earlier epoch for males than for females.

We have already considered the reasons for stating the death-rates of males and females separately, and at groups of ages, as well as the death-rate for all ages and both sexes, when it is necessary to set forth the vital statistics of a community. The death-rates of infants under 1 year, and of children under 5 years, are most important, as they afford positive evidence of the sanitary condition of a community. The death-rates of infants under 1 year should be stated as so many deaths in a year to 1000 children born and registered, and not as so many deaths per 1000 children living under 1 year, as the census returns under this head are usually inaccurate. For England and Wales in the 10 years 1871-80, the average number of deaths of male infants under 1 year to 1000 births was 163, of female infants 134, of both sexes 149.

The deaths of children under 5 should be stated as death-rates per 1000 living under that age. The average rate for male children in England and Wales (1871-80) was 68·14 per 1000, for female children 58·10 per 1000, of both sexes 63·12. No doubt some of this infant and child mortality, which is preventible, is due to other causes than insanitary conditions controllable by local authorities, such other causes being maternal neglect, insufficient and improper nourishment, etc. Still, just as Dr. Farr said, a sustained rate of general mortality above 17 per 1000 always implies unfavourable sanitary conditions, so it may be said that rates of mortality amongst infants and young children, which exceed the rates prevalent in the country generally, are indications of bad sanitary conditions in the communities in which they occur.

Besides the death-rates at various groups of ages, the death-rates from special diseases should be stated, both for all ages and at various groups of ages. The system of certification of the cause of death—although still very incomplete, both from errors in diagnosis and in proper nomenclature, and from want of certification amongst the very poor in large cities—enables the death-rates from special diseases, or groups of diseases, to be stated with some approach to accuracy. The death-rates from the principal zymotic diseases, from tuberculosis, phthisis, and acute diseases of the lung, afford the best evidence of sanitary condition. The principal zymotic diseases are:—small-pox, measles, scarlet fever, diphtheria, whooping-cough, typhus, enteric fever, simple continued fever, diarrhœa and dysentery, and cholera. Enteric fever mortality is the test *par excellence* of sanitary condition, caused as it is by specific fæcal contamination of air and water; whilst diarrhœa with its special incidence on young children, is notably associated with insanitary surroundings. The other zymotic diseases, although probably favoured in their onset and fatality by unhygienic conditions, also indicate, when the mortality from them is high, a failure on the part of the sanitary authority to control their spread by disinfection and isolation. Tuberculosis, phthisis, and acute diseases of the lungs, are most prevalent and most fatal amongst communities where overcrowding in dwellings or workshops is allowed to exist, or where sites are damp and the subsoil saturated with water. They may thus be taken as evidence of a certain class of insanitary condition, usually associated with poor town populations.

Annual Death-rate per 1000 *in the* 10 *years* 1871-80.

	England and Wales (Persons).	London (Persons).
All Causes . . .	21·27	22·37
Small-pox . . .	0·24	0·44
Measles	0·38	0·51
Scarlet Fever . . .	0·72	0·60
Diphtheria . . .	0·12	0·12
Whooping Cough . .	0·51	0·81
Typhus	0·06	0·05
Enteric Fever . . .	0·32	0·24
Simple Continued Fever .	0·11	0·07
Diarrhœa and Dysentery.	0·91	0·94
Cholera	0·03	0·04
Zymotic Diseases . .	3·47	3·90
Phthisis	2·12	2·51
Other Tubercular Diseases	0·77	0·98
Diseases of the Respiratory System . . .	3·76	4·60

The number of deaths at a special age-period, or from a special disease, must not be stated as a proportion of the total deaths from all causes; for a fallacy is involved in attempting to establish a relationship beween two factors, both of which are variable. In the first case also, the number of deaths at a certain age-period evidently will depend largely upon the number living at the age in question, and this number (proportion to all ages) may—as we have seen—vary considerably in different communities. In the second case, too, the special disease may be one affecting chiefly a certain age-period, and a like error will be involved. Dr. Ransome gives the following example of the fallacious character of such statements:*—a town A has a population of 100,000, with 2000 annual deaths, of which 500 are caused by phthisis. A town B has a population of 100,000, with 4000 annual deaths, of which 1000 are due to phthisis. The general death-rate of A is 20 per 1000, of B 40 per 1000. A's death-rate from phthisis is 5 per 1000, B's is 10 per 1000; but the proportion of deaths from phthisis to total deaths is 250 to 1000 in the case of both A and B; and judging from this test alone A would appear to suffer as severely from phthisis as B, although as a matter of fact its death-rate from phthisis is only half B's.

In this chapter an attempt has been made to indicate briefly the errors and fallacies that arise from the wrong use of vital statistics for comparing or contrasting the health and sanitary conditions of different communities, or of different classes of the same community. The importance of a right use of statistics, and of avoiding incomplete and erroneous deductions—which are, even now, far from uncommon in statistical expositions and

* *Vital Statistics* by A. Newsholme, M.D.

controversies—must be the author's excuse for attempting in so limited a space to treat of a very complex subject.

APPENDIX.

Standard Solutions for Quantitative Analysis.

1. For determination of Free and Albuminoid Ammonia.

A. *Ammonium Chloride,* 0·00315 grammes dissolved in 1 litre of distilled water free from ammonia. 1 c.c. = 0·01 milligramme of ammonia (NH_3).

B. *Nessler's Solution.*—Potassium iodide, 35 grammes, mercuric chloride, 13 grammes, dissolved by boiling in 1000 c.c. of distilled water. A cold saturated solution of mercuric chloride is then added until a slight permanent precipitate of the red mercuric iodide is formed. Solid caustic potash, 160 grammes, are then dissolved in the mixture, and the solution is rendered sensitive to ammonia by the addition, if necessary, of more saturated mercuric chloride solution.

C. *Alkaline Permanganate solution for Albuminoid Ammonia.*—Caustic potash, 200 grammes, potassium permanganate, 8 grammes, dissolved in 1 litre of distilled water. The solution is well boiled to drive off ammonia, and made up to 1 litre with distilled water free from ammonia.

2. For determination of oxidisable matters.

Permanganate solution.—Potassium permanganate, 0·395 grammes, dissolved in 1 litre of distilled water. 1 c.c. used with acid, yields 0·1 milligramme of oxygen, and oxidises 0·2875 milligramme nitrous acid (HNO_2). 100 c.c. are exactly decolorised by 100 c.c. of oxalic acid solution (0·7875 gramme of crystallised oxalic acid in 1 litre of distilled water).

3. For determination of chlorine.

Silver Nitrate, 4·788 grammes, dissolved in 1 litre of distilled water. 1 c.c. = 1 milligramme of chlorine = 1·65 milligrammes of sodium chloride.

4. For determination of hardness.

Soft soap, 17 grammes, dissolved in 1 litre of distilled water and methylated spirit (35 per cent.). The solution is graduated with a standard solution of calcium chloride (1·11 gramme to 1 litre). 1 c.c. = 1 milligramme calcium carbonate ($CaCO_3$).

5. For determination of nitrates.

Pure *sulphuric acid* 8 vols., and pure *phenol* (carbolic acid) 1 vol., are mixed, and then heated for several hours at 100° C. One volume of this solution is mixed with 3 volumes of distilled water for use.

6. For determination of carbonic acid.

Crystallised *oxalic acid*, 2·84 grammes, dissolved in 1 litre of distilled water. 1 c.c. exactly neutralises 1·26 milligrammes of lime (CaO) = 0·5 c.c. of carbonic acid (CO_2) at 0° C.

The standard soap solution, the standard permanganate solution for oxidisable matters, and the standard oxalic acid solutions must be freshly prepared, as when kept in stock they rapidly deteriorate.

NOTE.

The Flashing Point of Petroleum Oils.

The old act of Parliament prescribed 100° F. as the flashing point of petroleum oils, with what is called the "open cup" test. This was repealed in 1879, and a minimum of 73° F. with the "close cup" test was substituted; but the new test being more delicate and precise, the flashing points by the old and new methods are practically identical. The flashing point is defined as "the temperature at which a sample of petroleum oil commences to give off sensible quantities of inflammable vapour."

Soaps of Commerce.

Soft soaps are principally oleates of potash, but contain also some stearate of potash.

Hard soaps are principally stearates of soda, but they contain, besides, a little oleate of soda, also palmitate and resinate of soda, where palm oil and resin are used in their manufacture.

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