water. From rivers and pools the water sample must be collected some distance from the shore by sinking the bottle and then withdrawing the stopper, so as not to collect any substances which may be floating on the surface. As bits of duckweed, straw, &c., would make a great difference in the percentage amount of suspended matter found by this method, it is important that they should be either excluded when taking the sample or removed mechanically before analysis.

# CHAPTER II.

## *ANIMAL AND VEGETABLE IMPURITIES.*

EVEN in these days, when the importance of the laws of health is so generally recognised, and the nature and causes of disease are receiving every day fresh light, we are occasionally confronted with the argument that a water condemned by chemists and bacteriologists cannot be so dangerous as it is represented, since it has been drunk by many people with apparent impunity, or at any rate with no direct production of disease.

It would hardly be worth while to combat such a contention, in the face of the opposite propositions that have been demonstrated by recent visitations of cholera and by the periodic severe outbreaks of typhoid and other water-borne diseases, were it not that the argument is constantly used to fortify the objection of expense, with the effect of quashing or delaying local schemes for obtaining a proper supply of pure water.

M. Monod, Director of Public Health in France, examined the mortality of twenty-four towns for two years before and two after they had been supplied with a purer water. In three there had been no change (perhaps the water had not been really improved), but in twenty-one it had been reduced from twenty to thirteen and a half per 1,000, and fatal cases of typhoid had almost disappeared.

There is no doubt that a robust system may be trained to an extraordinary tolerance of substances otherwise poisonous. The peasants in Styria, for example, are accustomed to eat arsenic without ill effects, and heavy drinkers and opium-eaters might contend that alcohol and opium could never do harm.

Under ordinary circumstances the body in health possesses a considerable power of resisting the germs of disease and of actually destroying them in the blood. But this process itself is a drain on the vital resources, and if at any time the system be enfeebled, or the activity of the contagion be intensified, the natural resistance is overpowered, and the disease has its way. When once the disease is established in some weaker member of the community, its spread as an epidemic is rendered more likely, and then even the strongest succumb.

It is not pleasant to enumerate the different kinds of filth and polluting matter which have been found by the microscope in drinking waters. It is obvious that *anything* may get into water that is unprotected. Less trouble is often taken to guard this most important food than is used for meat, bread, or other necessaries. Milk is carefully covered, provisions are kept in safes with wire or perforated casings admitting air and excluding dirt, but water is stored in open cisterns rarely cleaned, or directly drunk from streams that are open to every kind of contamination.



Dead animal matters are of more dangerous import than vegetable, as the former may indicate direct contamination by a living animal, and even if only introduced with dust, they are quite capable of being a vehicle of contagion. Hairs are often found, and may be easily identified as the product of a particular animal, such as a human

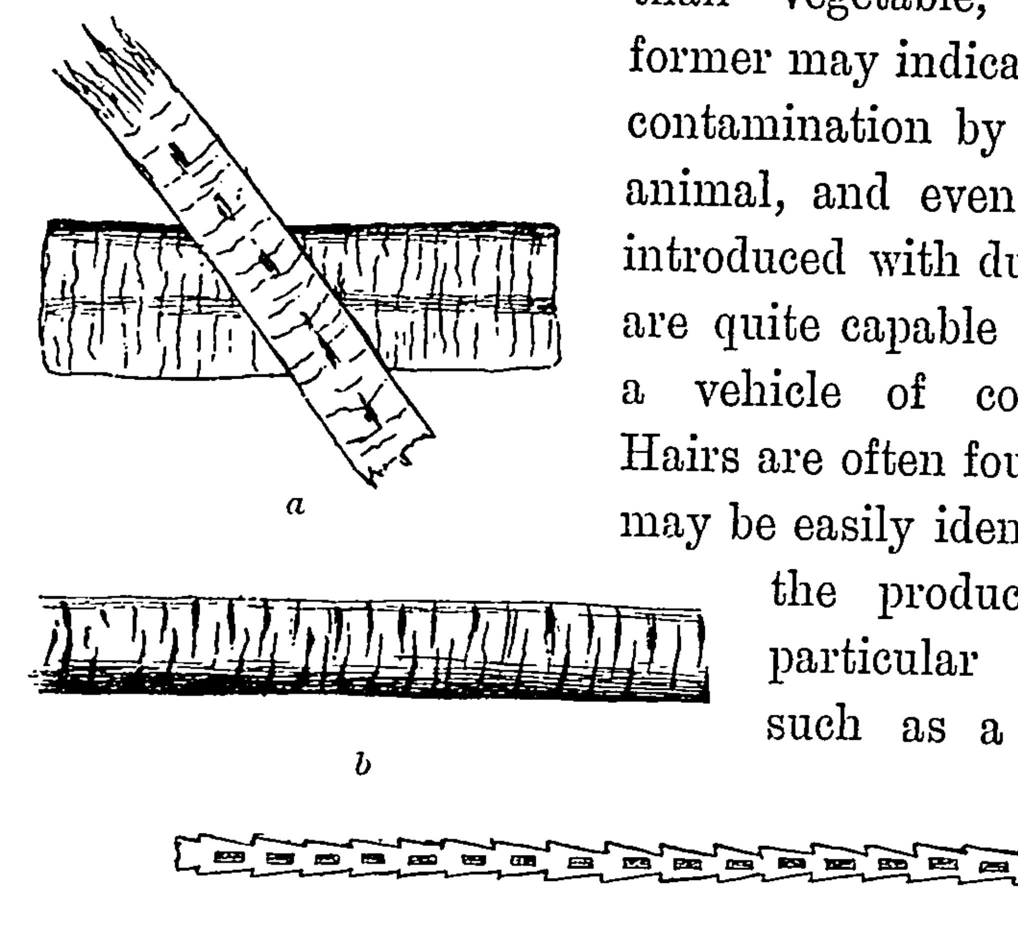

FIG. 1. *a*, Human hair; *b*, hair of rat; *c*, hair of mouse.

being, dog, mouse, &c. (Fig. 1). Epithelial scales (Fig. 2 and Fig. 5 *b*) from the lips or from the excretory organs are met with, and are a very bad indication. Even the dead bodies of animals, such as mice, beetles, frogs, and worms, have been repeatedly found in uncleansed water cisterns and reservoirs. Wing-scales of butterflies

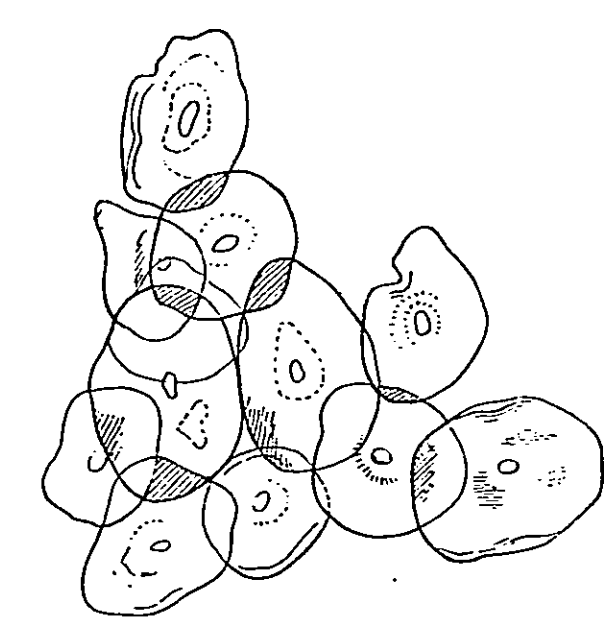
FIG. 2. Epithelial scales.

and moths and parts of insects are occasionally present. An acarus of a species allied to the cheese and sugar mites, but also belonging to the same family

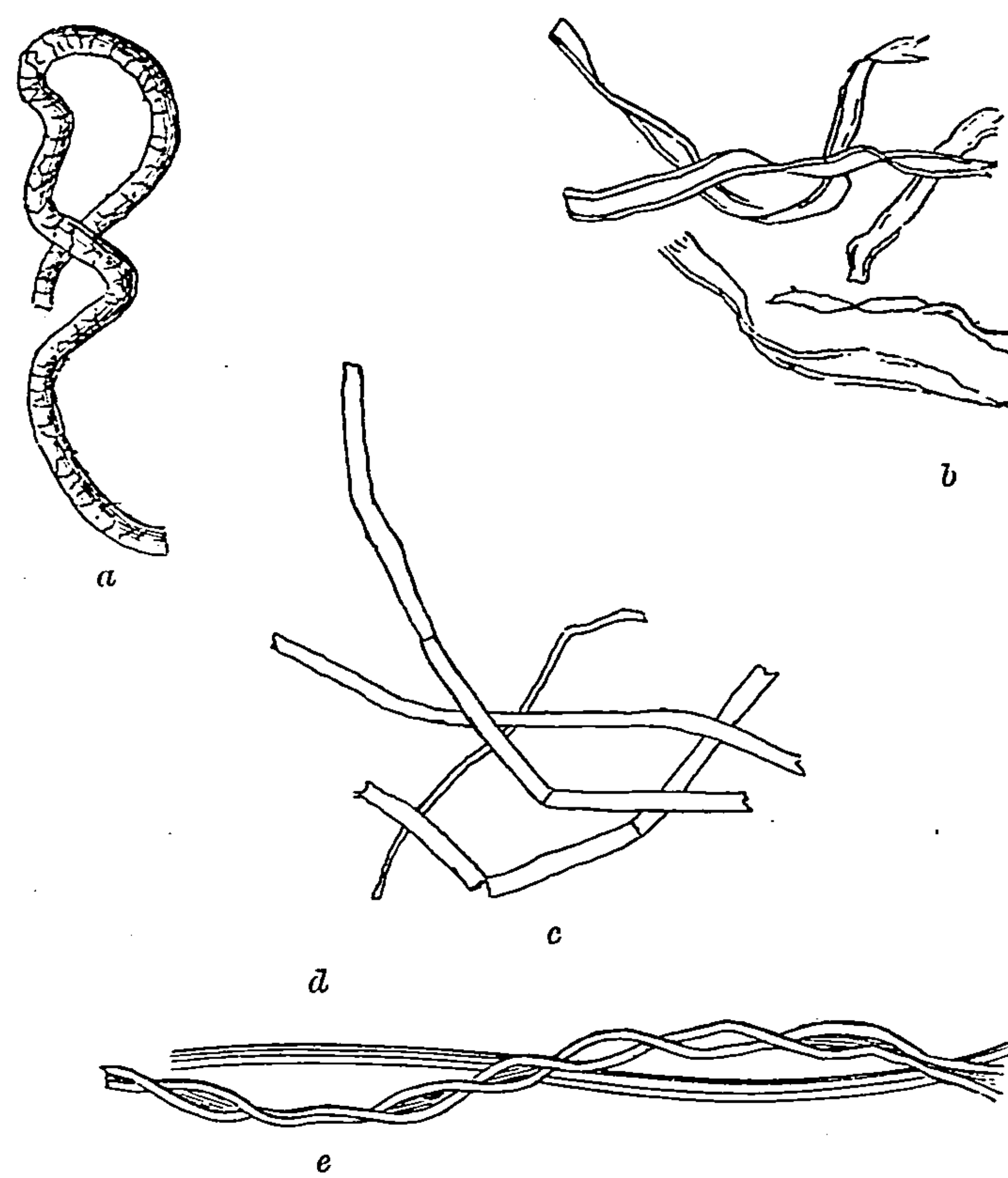


FIG. 3. *a*, Wool; *b* and *e*, cotton; c, linen (flax); *d*, silk.

as the itch insect and several animal parasites, sometimes occurs in the London waters derived from the Thames (Fig. 10, p. 28).

Fibres of clothing, sometimes dyed, are of frequent occurrence, and may be identified under the microscope as silk, cotton, linen, or wool (Fig. 3). They usually



point to contamination, but cotton and linen fibres in the water of drinking vessels generally arise from the cloths that are used to wipe them. Particles of muscular fibre (Fig. 4), when found in drinking water, are considered to be evidence of contamination with fæcal matter. Lionel Beale has pointed out that actual fragments of fæces can be identified under the microscope (Fig. 5).

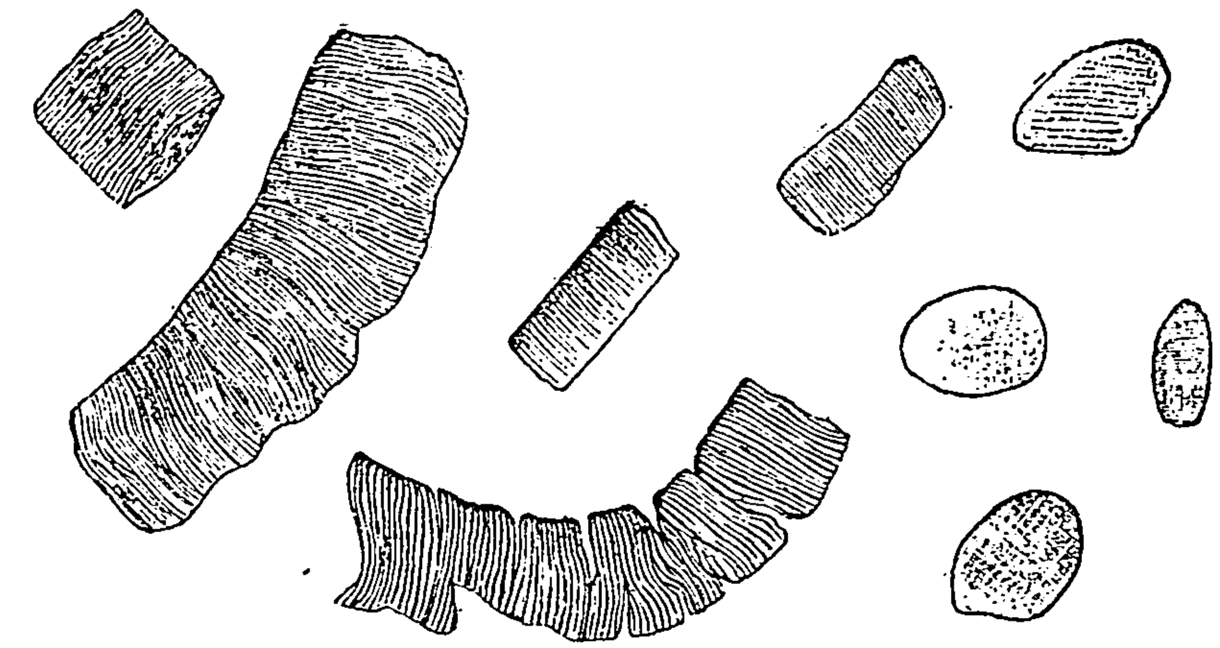

FIG. 4. Muscular fibre partially digested found in outfall sewer near Trinity Ballast Office (Lionel Beale).

Splinters of various woods are common, and those of deal or fir-wood are known by the rows of pitted markings in the fibres (Fig. 6). Plant hairs (Plate I.), spiral vessels, epidermis of leaves, fragments of straw (Fig. 7) and of the coverings of seeds, especially those of the cereals, and vegetable tissue more or less discoloured from decomposition, are met with in a large number of waters; if at all frequent, an excess of vegetable impurity is to be suspected.

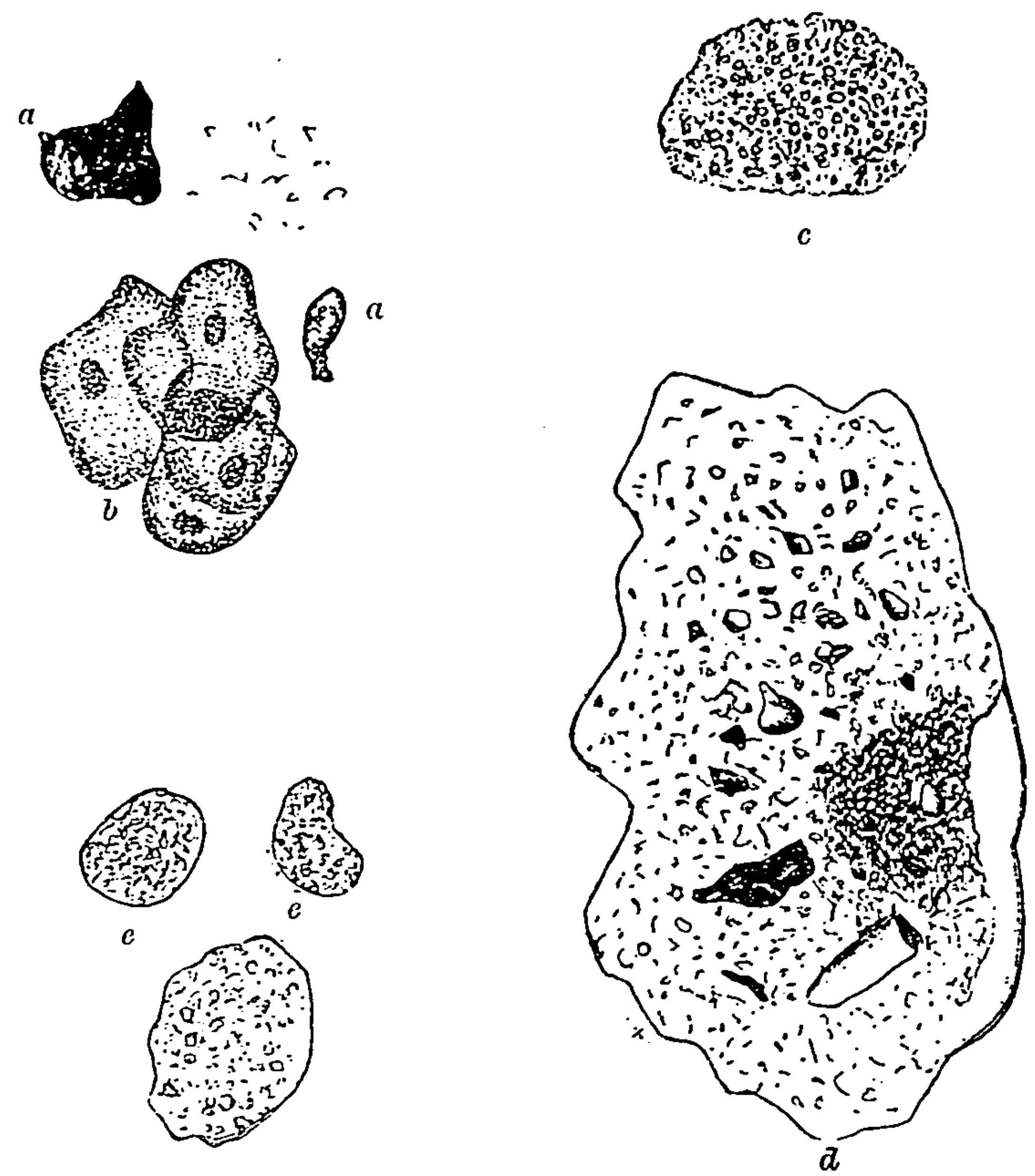


FIG. 5. Substances found in sewage-polluted water (Lionel Beale). *a*, Fragments of coal; *b*, epithelial scales, probably from mouth; *c*, yellow fæcal matter disintegrating; *d*, mass of fæcal matter siliceous and other fragments embedded in its viscid substance; *e*, fæces with granules and oil globules.

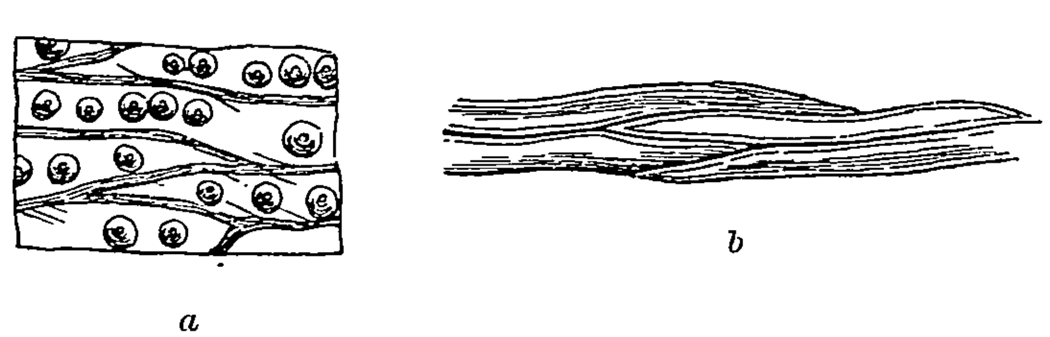


FIG. 6. *a*, Fir-wood, showing pitted markings; *b*, ordinary woody tissue.

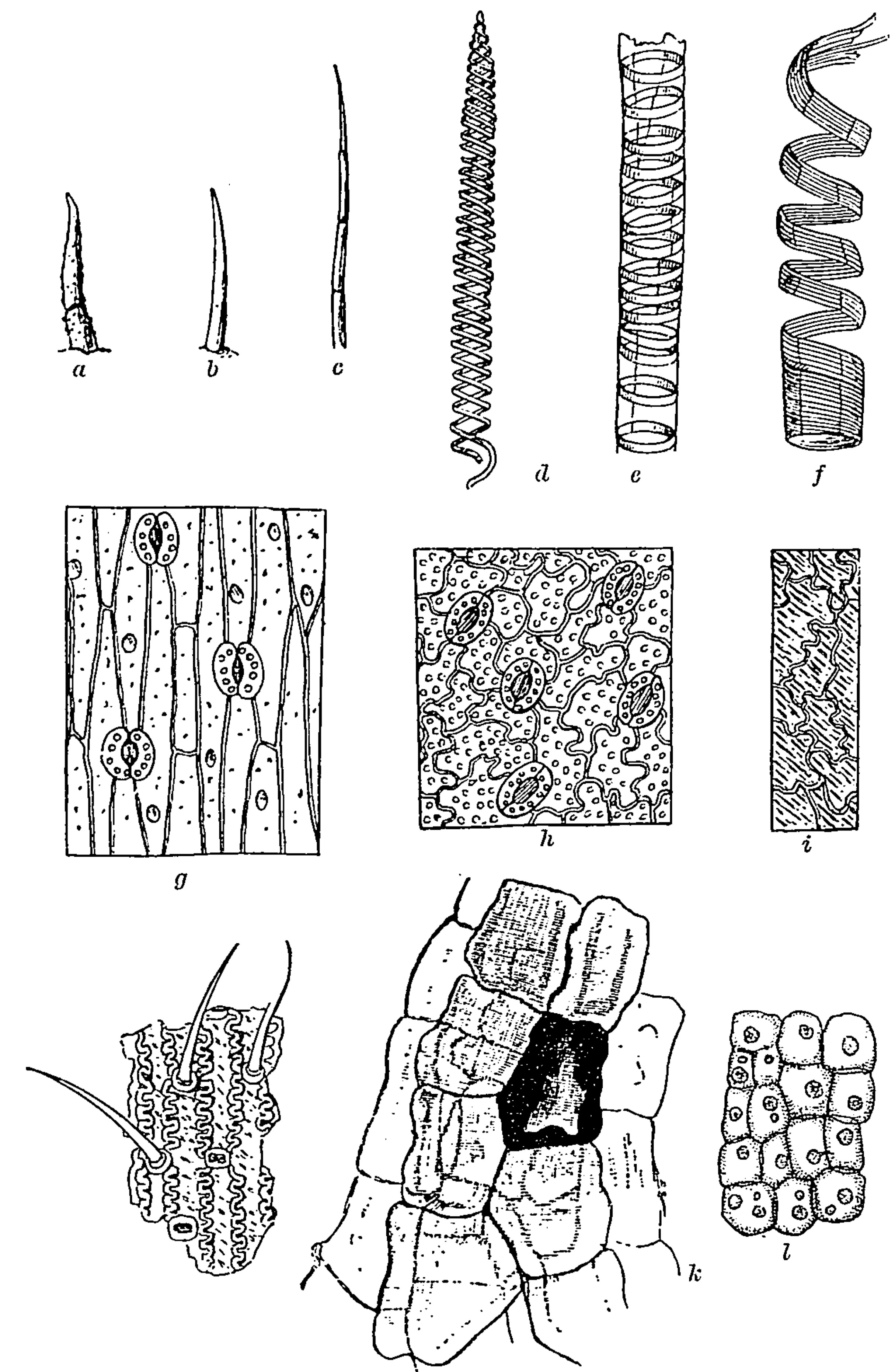


PLATE I. Illustrations of vegetable impurities. *a*, *b*, *c*, Plant hairs; *d*, *e*, *f*, spiral and annular vessels; *g*, *h*, epidermis of leaves; *i*, coat of seed showing star-shaped cells; *j*, epidermis of wheat; *k*, vegetable cellular tissue found in sewage undergoing decomposition; *l*, young vegetable cellular tissue.

Pollen granules (Fig. 8) from flowers are frequently wafted into waters in the country. Wheat starch

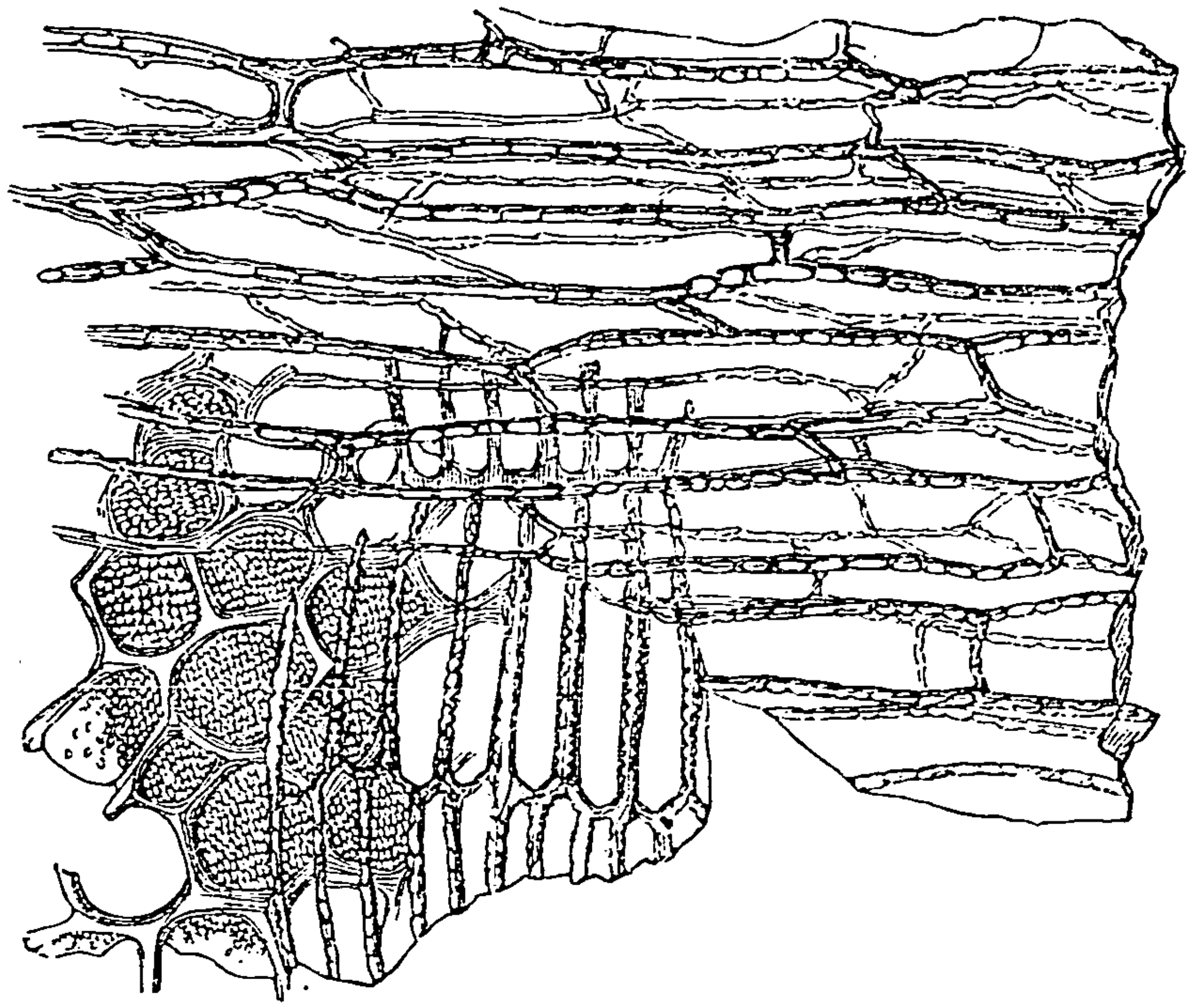

FIG. 7. Fragment of Straw.

from flour and occasionally potato and other starches are found. All these are important as evidences of

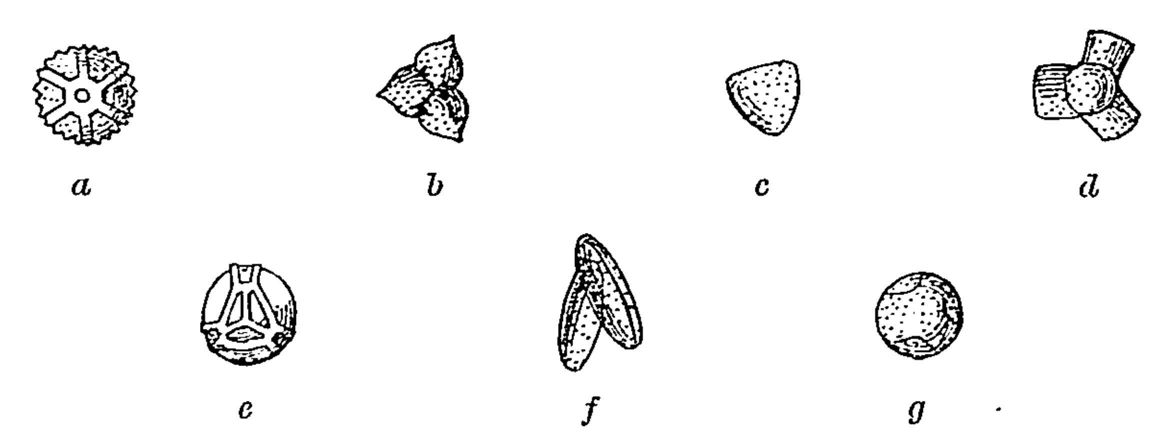


FIG. 8. Pollen granules. *a*, Dandelion; *b*, heath; *c*, liliaceous plant; *d*, heath; *e*, sowthistle; *f*, furze; *g*, violet.



bad filtration or careless storage (Fig. 9). It has been pointed out that starch granules and hard portions of food pass undigested from the intes-


FIG. 9. Starch granules. *a*, wheat; *b*, potato; *c*, oat; *d*, maize; *e*, rice.

tines, and hence may be derived from sewage contamination.

Living animals found in water comprise members of all the natural families. Fish are an indication that the water is well aerated or contains a considerable amount of dissolved oxygen. As a river becomes increasingly foul the fish disappear, and in the case of the Thames, for instance, the improvement effected

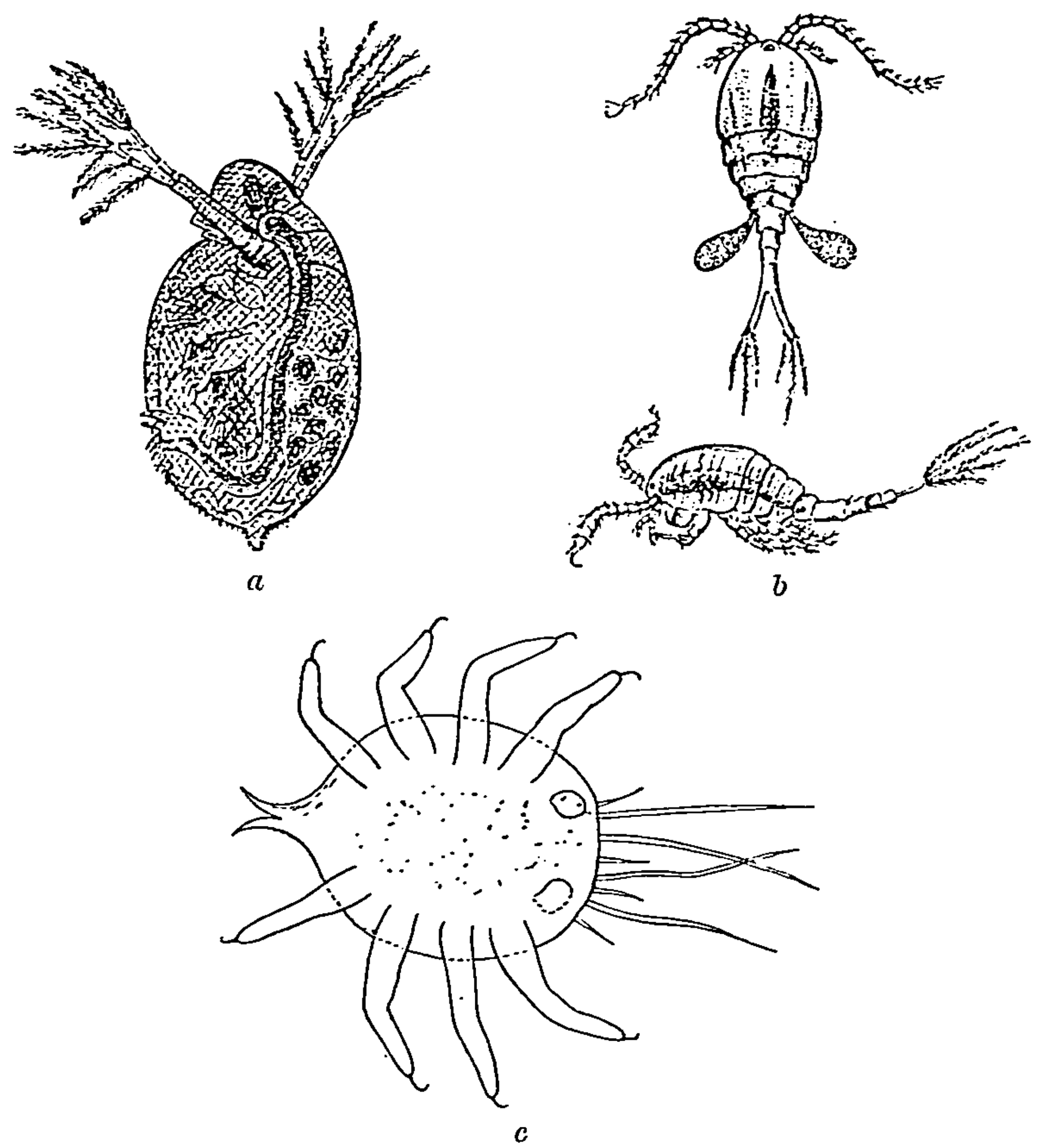

FIG. 10. *a*, Daphnia pulex; *b*, Cyclops quadricornis; *c*, Acarus (dead).

by the construction of the embankment and of the great main sewers and outfall works has been accompanied by the ascent of whitebait and other fish to the upper tidal reaches. At the end of 1895, a large



number of excellent whitebait were actually taken by the London County Council from one of the effluents of the sewage filters at Barking. But it must be remembered that fish in large numbers are often seen to congregate at the mouths of sewers where fæcal matter is visibly floating, being attracted by fragments of food and insects carried down by the sewage. Fish, in fact, are more affected by muddy water and by chemicals from factories than by excreta, so that their presence is by no means conclusive that a water is not dangerous for man to drink.

Among minute animals living in water, a few are visible to the naked eye, such as the water flea, *Daphnia pulex*, and *Cyclops quadricornis* (Fig. 10). A small round worm, called *Anguillula fluviatilis* (Figs. 14 and 15) is common in rivers and ponds, and sometimes makes its way into London waters. It is believed to be capable of living in the human intestine, and therefore might be dangerous, and must be regarded as a very bad feature in a potable water.

On numerous occasions letters to the papers have asserted the presence of small eels in the water drawn from the taps on constant supply. It would appear that eels and sometimes other fish have been found in the mains, and house-pipes have sometimes been stopped by their bodies. Their occurrence had been traced to accident or malice, and in one or two instances the bye-pass of a filter bed, used in reversing the current so as to wash out the impurities, has been improperly left open. No filter bed could permit the spawn of fish, still less the animals themselves, to penetrate unless it contained channels, formed by too rapid running or by careless laying, as has sometimes happened, that would allow unfiltered water to pass. There is proof that in many cases, both in times of flood and in seasons of scarcity, water imperfectly filtered or not filtered at all has been allowed to gain access to a town supply.

Protozoa, like *amœba*, are looked upon as a bad sign; they are most frequent in badly aerated waters containing much organic matter. Some of them have been recently proved to be pathogenic. Piana and Galli-Valerio, in the blood-corpuscles of dogs which sickened of fever and jaundice after a few days' hunting in a marshy locality, found a pyriform protozoon called *Pyrosoma bigeminum*, similar to those discovered by Smith and Kilborn in Texas fever (*Moderno Zooiatro*, May 10th, 1895). Dr. Schurmayer, in the case of a child seized with cramps, vomiting, and diarrhœa, found in the intestines large numbers of flagellate infusoria.

Most medical authorities agree that malaria is communicated by organisms in water rather than by air. Some of these are undoubtedly protozoa.

The large class of vegetable organisms commonly known as *infusoria*, many of which are motile and contain green matter or chlorophyll, are broadly divided into *flagellate*, or moving by whip-like appendages,



and *ciliate* (Fig. 11), having rows of vibratile filaments, or cilia, over parts of their bodies. Large rotifers, vorticellæ, and other forms occur in water sediments (Figs. 12, 13, 14, and 15). These organisms are found in waters remote from any chance of animal contamination; hence their significance is confined to the fact that, if they are in large numbers and actively moving, there must be also present a large quantity of matter to serve as their food, such as, of course, would also supply plenty of nutriment for directly dangerous

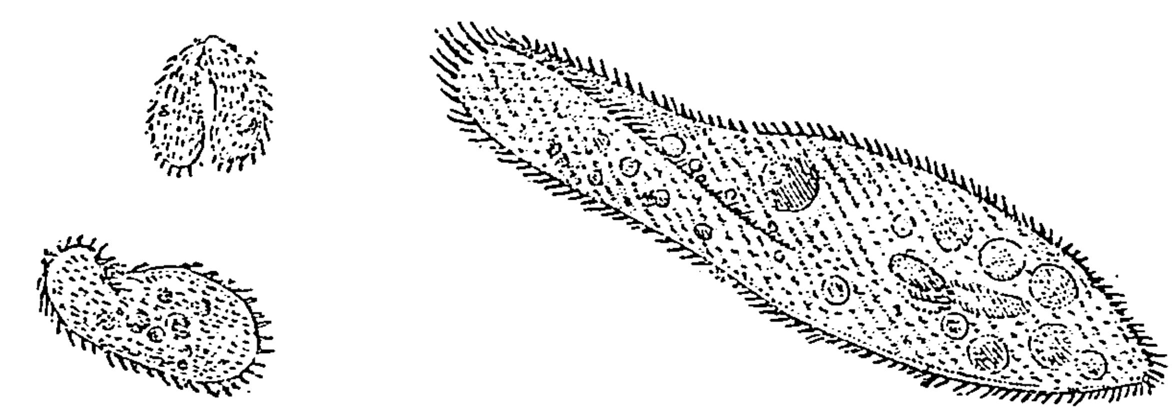

FIG. 11. Ciliate infusoria.

organisms. Apart from vegetable matter in solution in unusual quantity being known to be laxative and enfeebling to human beings, the water is likely to favour the rapid multiplication of any microbes of disease that might accidentally enter, and thus would contribute to the propagation of any epidemic.

Diatoms and desmids in small numbers occur in excellent waters. Filaments of convervæ are generally derived from the stones or walls of the source. Water weeds in moderate numbers effect a purification of the liquid by the oxygen they give off from their leaves. In aquaria this improvement in the quality of the water may be seen; but in rivers, if the growth is too luxuriant, the flow of the stream may be retarded and the water may be fouled by the

FIG. 12. Nos. 1, 2, 3, 5, 7, 9, Infusoria; 8, Vorticella; 11, 28, Paramœcia; 12, 19, Convervæ; 13, 14, 15, 16, 27, 33, Diatoms; 26, Desmid; 6, Anguillula fluviatilis; 17, 18, 20, 25, 29, Vegetable fibres; 24, Torula. (After Hassall.)

decay which would then take place. A very good idea of the character of a stream or river may be formed from an inspection of the kinds of plants growing on its banks. When such growth is very



luxuriant, and the stems and leaves of the plants are succulent, then a pollution of the river with sewage is to be suspected. A pure mountain stream shows either no, or only very stunted and slight, vegetation.

FIG. 13. Water from a well near the Seine at Paris. 1, Cyclops; 2, Mycelium with spores; 3, Woody débris; 4, Zooglœa; 5, Humus.

Sedges and flags grow in a water which is running and aerated. Smaller rushes and marsh plants indicate a brown, peaty, stagnant water, which is probably unwholesome for drinking.

The spores of fungi, and more especially the interlacing threads called mycelium, are usually accompanied by a flatness and want of aeration in the water. Artesian wells, like those at Grenelle, near Paris, and

FIG. 14. 1, 5, Desmids; 2, 3, 4, Diatoms; 6, Infusoria; 7, Daphnia pulex; 8, an Entomostracan; 9, Anguillula; 10, Muscular fibre; 11, Vegetable tissue and earthy matter; 12, Cotton fibre; 13, Fungus mycelium; 14, Cladophora (an alga).

occasionally those sunk in the chalk belonging to the Kent Water Company, yield waters showing fungoid filaments and a few diatoms; these are found in the sediments of such waters, which sometimes contain also



crystals of carbonate of lime, particles of chalk, oxide of iron, and silica (quartz or sand). Deep well waters which have been out of contact with air for a long time are wanting in the usual amount of dissolved

FIG. 15. Water organisms in the Seine at Port à L'Anglais (G. Neuville).

oxygen. The few micro-organisms found in such waters probably drop in from falling atmospheric dust, and when growths of organic matter occur in deep well waters, usually they may be traced in such accidental origin, and can be prevented by covering the well. In less pure waters one frequently finds that in the darkness of the water-pipe filaments of considerable length grow, and sometimes to such an extent that the valves and taps become choked.

It is very important that all drinking waters used by man should be kept away from animals, as parasitic maladies, like tapeworm and hydatid disease, have been frequently traced to water which has been polluted in this way. Dogs are especially liable to such diseases, and in Queensland it is said that the shepherds, while not too particular as to the water they drink, refuse to make use of any which bears evidence of having been drunk by a dog. Sheep and other animals may also convey parasites, so that it is imperative to avoid drinking any pond or brook water unless it has been filtered or boiled. The danger is more imminent in tropical countries, as in India, where the germs of a filaria, or kind of thread-worm, have been several times discovered in the waters of tanks and streams. *Filaria dracunculus*, the guinea-worm, was proved by Hirsch to be communicated by drinking the foul water of streams. Many other species of parasitic worms have also been traced to water, and animals often suffer from epidemics which have originated in this way (Fig. 16).

Fresh-water sponges occur as soft, fibrous masses of brown or greenish colour in tanks and water-butts where the liquid is continually in motion. When



they die, the spicules which form their supporting skeletons are liberated, and may be detected in the water sediment by the microscope as minute pointed bodies of characteristic shape (Fig. 15, No. 15). The brown or grey sponges occasionally grow in water-mains and cause obstruction, and the products of their growth and decay contaminate the water, and

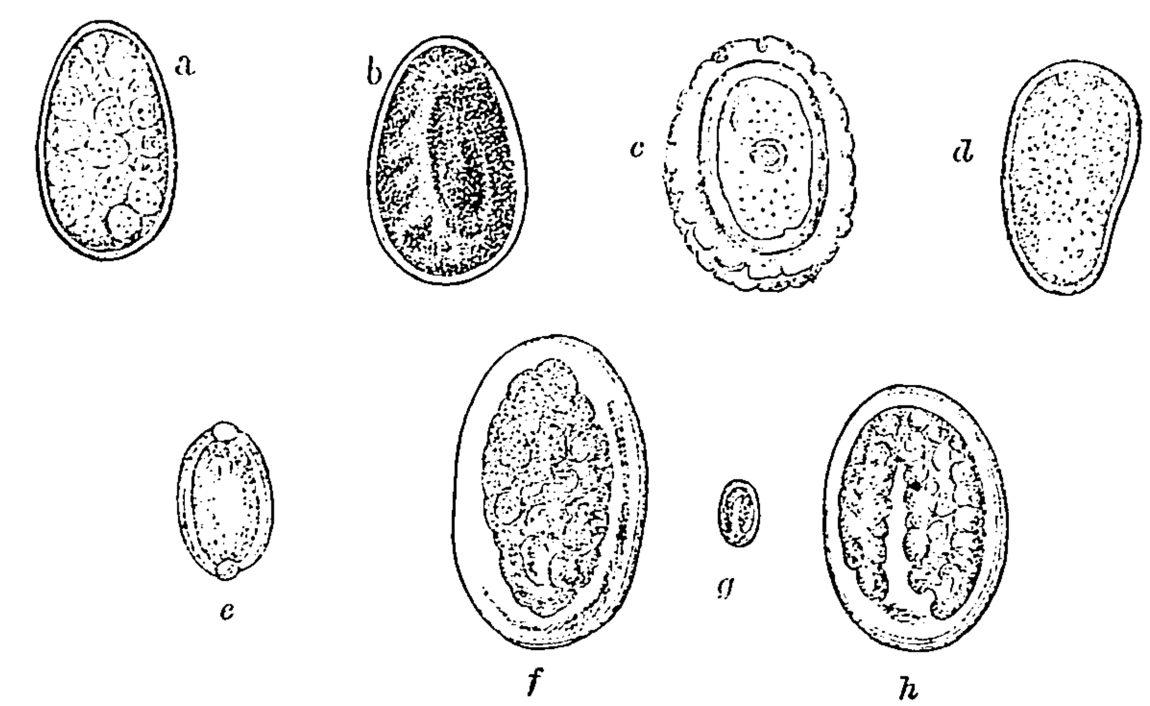


FIG. 16. Eggs of parasitic worms. *a*, *b*, Botryocephalus latus; *c*, Ascaris lumbricoides; *d*, Oxyuris vermicularis; *e*, Trichocephalus dispar; *f*, *g*, *h*, Anchylostomum duodenale in different stages.

occasion an unpleasant odour and taste. They thrive most in summer, and will not grow in a water properly filtered and therefore free from the organisms which constitute their food; consequently the presence of sponge spicules in a sediment is a bad indication.

The sanitary significance of the presence of living organisms in water rests chiefly in the fact that where they are thriving there must be an adequate supply of their appropriate food. Green algæ require the presence of considerable quantities of mineral ingredients, such as lime, salts of potassium, ammonia, and nitrates, which can all be derived from sewage, while certain crustacea and infusoria feed upon solid organic matter undergoing decay.

A green unicellular alga, a species of protococcus, is frequently seen encrusting decanters in which water has been allowed to stand.

It is found that the growth of green algæ can be prevented by excluding light from the water during storage. With this object, as well as to protect from dust and smoke and to prevent freezing in winter, reservoirs and wells are often covered over with brick arches. On the other hand, the beneficial effect of light in destroying the germs of disease (p. 149) is in this way hindered or lost. The algæ are infinitely less dangerous than the pathogenic bacteria, and as they undoubtedly cause a disappearance of some of the organic matter present, their presence may be useful in some cases.

The most important of the solid bodies present in water are those living organisms known as microbes or bacteria, which are invisible to the naked eye and to the lower powers of the microscope. Under higher powers, they appear as minute points or as moving rods, which congregate together into groups and lines, but sometimes associate in pairs or form long segmented filaments (p. 253). To make out their form



and structure requires the highest powers, and sometimes immersion lenses and special illumination. Even then these minute forms of life frequently so resemble one another that further experiments are necessary before it is possible to form any conclusions as to the species to which they belong. Their cultivation and isolation require considerable care, and their importance has increased since the discovery of the close connections which exist between certain diseases and these microbes. A bacteriological examination of a water is therefore as necessary as a chemical analysis, if it is required to ascertain the absence or presence of specific disease-producing organisms.

It is a familiar fact that yeast is capable of converting sugar into alcohol and carbonic acid, and that, when examined under the microscope, it is seen to consist of round cells of a species of fungus called *Saccharomyces*, or *Torula, cerevisiæ*. Many years ago, Döbereiner proved that, before alcohol was formed, an intermediate body called "invert sugar" was produced, and other investigators noticed that similar changes could be effected in starch without the presence of any living cells, provided a substance called diastase, which exists in malt, was present. Liebig argued from these facts that diseases might have a similar origin, and, from the idea of *contact*, the theory was called "catalytic." It was consequently recognised that many matters undergoing change could propagate that change to other unstable molecules near them. Diseases were therefore presumed to be due to the action of organic ferments, or "enzymes," from which idea such affections were termed "*zymotic*" (ζυμα, yeast), a term which is still retained. As a consequence of this theory, *all* organic matter in waters was looked upon with suspicion, and the determination of its amount by chemical analysis was regarded as a measure of the wholesomeness or otherwise of a potable water.

But Pasteur subsequently proved that, provided the living cells of yeast were excluded, no fermentation took place, and that substances and temperatures which hindered the growth of the ferment also hindered the change into alcohol and carbonic acid; that, in fact, the fermentation was a vital act of assimilation and excretion on the part of the fungus, that the sugar was really its food, and the other products its excreta. He further demonstrated that germs conveyed by dust and from water were the causes of change in milk, blood, broth, &c., and if the germs were killed by boiling or removed by careful filtration, and the liquids, contained in a perfectly clean vessel or one that had been sterilised by heat, were then protected from dust by plugs of sterilised cotton wool, that then the fluids, although perfectly accessible to air filtered through the wool, would remain without putrefaction for an indefinite period. Since disease presented many analogies to putrefaction,



he developed the germ or microbic theory of disease, which is now established by subsequent investigators for several of the more dangerous diseases, and is believed to explain the origin of many others.

Pasteur himself and his pupils, by long-continued investigations, succeeded in demonstrating the existence of bacteria in the blood and tissues of infected patients, and by inoculating animals with cultivations of these bacteria proved that they were pathogenic, or capable of producing all the symptoms of the disease. A very large number of bacteria have thus been studied, and their characteristics described, but subsequent research has shown that in some cases what have been described as apparently different forms are merely transitional stages in the life history of a single species. The variations in the conditions under which the organism lives, the temperature and the food, and other circumstances, have to be carefully studied before the true nature of an organism can be ascertained. In some cases these variations produce such changes in the physiological action and structure of the organism that its nature is entirely altered. Thus the bacilli of anthrax, or wool-sorters' disease, sometimes pass into what is known as the spore condition, and in this state, according to Koch, will remain dormant for months, perhaps for years, until they reach the temperature of 16° C. (62° F.), when they will again commence to grow and multiply. The mature organisms, on the other hand, when placed in Thames water at 12° C., according to Percy Frankland, disappear in less than five days; they are also killed by a much lower temperature than that which destroys the spores. As a general rule, the spores of bacteria, like the seeds of higher plants, are possessed of much greater vitality than the fully developed organism, the latter being killed by a temperature of 60° C. or less, and more easily destroyed by disinfectants, while the spores can withstand any temperature below that of boiling water for a considerable time, and are also less affected by chemical reagents. Cold and dryness have little effect on the spores. On account of this variability, although the number of species of bacteria have been greatly reduced, the difficulty of identifying a particular bacillus and following its life history has been considerably augmented.

It is only a few bacteria which, up to the present time, have been definitely branded as "germs of disease." As all natural waters contain microbes, and some immense numbers of them, and as they are almost universally distributed through the air and in our food, it is fortunate that the majority are harmless and even useful to man by destroying organic matter, which they turn into carbonic acid, water, ammonia, and nitrates. It is also more than probable that these harmless bacteria which exist in waters wage war upon any pathogenic organisms that may be present, either by starving them out or



by poisoning them with the products they excrete. In this latter way they even render the water unfit for themselves to live in, and dying, sink with the sediment to the bottom. Such a process naturally happens in settling reservoirs. Percy Frankland demonstrated that ordinary surface waters, like that of the Thames, were capable of rapidly getting rid of certain injurious bacteria, independently of the further multiplication of the common water organisms, and, therefore, attributed the action not to "crowding out," or "struggle for existence," but to the elaboration of products by the latter, and possibly also by vegetable life, which are inimical to, for example, the typhoid bacillus. Frankland added this organism to Thames water, and found that it disappeared in nine to thirteen days, whereas in the purer deep well water of the Kent Company it survived for thirty-three to thirty-nine days (Proceedings Royal Society, lvi. 543).

The fact that the excretory products of bacteria are inimical to bacteria themselves is the foundation of the processes of inoculation against disease. The microbes are grown abundantly in a "culture medium," which is filtered through porcelain to remove the organisms, and the liquid containing the products of their lives is found on injection into the veins of animals to be more or less protective against their future inroads. Duclaux, indeed, has termed these bacteria "the scavengers of the waters." Natural purification, then, by subsidence, light (p. 150), oxidation, and life action, accounts for the fact that, though myriads of disease germs must pass into rivers from the drainage and sewage polluting their upper course, they can rarely be discovered in the water after a flow of a few miles. Dr. Tidy contended that a few miles of flow were sufficient to purify any river, but the contention is not a safe one, since, if any survive, transplantation into a purified water will cause them to recommence multiplication with extraordinary vigour, and may give rise to a fresh outbreak. Many epidemics which have often suddenly occurred may be explained in this way. It is also important to note that a water is not necessarily wholesome because by bacteriological examination it is found to be sterile, or free from microbes, as in that case a "sterilised"—*i.e.*, perfectly filtered or heated—sewage would be fit for drinking, whereas it might be poisonous from the presence of "ptomaïnes," or other products of bacterial growth, or might be injurious from excessive quantities of mineral salts. A chemical analysis is, therefore, always necessary, in addition to a bacteriological examination, before a reliable opinion can be formed upon the purity of a water.

The distribution of bacteria in water is modified by every shower of rain, as the rain carries down large numbers of organisms or their spores floating in the air. Miquel, Hare, and others have shown that the number of micro-organisms in the air rapidly decreases as we ascend; therefore the water of upland surfaces



at first contains very few. Surface waters that are still or in very slow motion develop large numbers; but as they are always depositing, in lakes they are almost absent. Rapid streams flowing over gravelly beds generally become purified from microbes, though they may be turbid from mineral matter, and springs at their origin are usually free from life. Rivers contain the drainage of their entire basins, and must necessarily hold a collection of all the surviving organisms of the land, of the air, and of the towns and villages that they have passed. A river in flood contains, of course, a larger number and variety than at ordinary times. Sea water has fewer microbes, and is a conspicuous example of a water that would pass a bacteriological examination and yet would not be potable.

The two zymotic diseases which have been directly traced to special bacteria in drinking water are Asiatic cholera and typhoid fever, whilst diphtheria has been proved to have originated from impure milk. In many other diseases the causation by water is almost certain, although the bacillus has not been found. There are a large number of instances in which typhoid seems to have been specially due to bad water. Many of them are given in the reports of the Medical Officer of Health of the Local Government Board from 1868 to the present time.

The bacillus of anthrax, or splenic fever, is of common occurrence in hair, wool, and fur, and is easily transferred to water, in which its spores were found by P. Frankland to be capable of surviving for two years, besides enduring great variations of temperature. An outbreak of the disease in Wurtemburg (*Zeitschrift für Hygiene*, viii. 179) was traced by Rotz to water, while Diatroptoff found the bacillus anthracis in the mud of a spring (*Annales de l'Institut Pasteur*, 1893, p. 286). Consequently there is danger of this disease being transmitted to a river water from wool-scouring or fur factories or tanneries on its banks. Fatal cases of anthrax, or "wool-sorters' disease," periodically occur in London.

The outbreak of enteric fever in the Tees valley in 1891-2 is a good illustration of a water-borne epidemic. According to Dr. Barry, two sudden and marked outbursts of this disease occurred at a time of year when they were not usual. The localities supplied with water from the Tees suffered very heavily, while others not so supplied escaped. This river is subject to the grossest fouling by human excreta, and, previous to the epidemics, sudden floods washed vast masses of the filth which had been accumulating on its banks down the stream up to and past the points of intake from where the water was being pumped, after a doubtful filtration through gravel and sand, and delivered to certain populations. It was these populations that suffered from the exceptional prevalence of enteric fever. Dr. Thorne Thorne remarks, "Seldom has the relation of water so befouled to the wholesale occurrence of enteric disease been more obvious" (Report of the Medical Officer to the Local Government Board, 1893). This evidence, however, was not deemed conclusive by the Royal Commission on the Metropolitan Water Supply.



Although typhoid is, without doubt, water-borne, the difficulties attending the isolation and identification of the typhoid bacillus make it often impossible to prove its presence in waters which have certainly been the source of the disease. On removal, however, of the pollution, the disease has disappeared, so that the connection is undoubted. Although it appears to be established that organisms survive for long periods in soil, they die rapidly both in sewers and rivers. Parry Laws and Andrewes, in a recent report to the London County Council, state that they failed to find the typhoid bacillus on careful bacteriological analysis of many sewages, and only discovered it in sewage from the *main drain* of the Homerton hospital when forty cases were under treatment, and the disinfection of the stools had purposely been discontinued for two days previously. As to cholera, the reports of the visitations of 1854 and 1866, and of the epidemic of Hamburg in 1892, leave no doubt as to the agency of water in propagating the disease.

A great number of bacteria live in soil, a few of them pathogenic, such as *Staphylococcus pyogenes aureus*, an organism that may be the cause of wounds festering so frequently when dirt enters them.

These bacteria naturally find their way into the water of shallow wells. Among the many ways in which dangerous organisms may gain admission to water, drainage from cultivated and especially manured land, sewage of towns, cesspools, privies along the banks of streams, animals drinking from or discharging into wells, springs, or watercourses,* and the floating dust of the atmosphere are the most prominent.

* Besides anthrax and typhoid, glanders, hog and chicken cholera, and diphtheria have been thus occasioned in animals, and in some cases have been undoubtedly transferred by their milk or flesh to man.

# CHAPTER III.

## *DIFFERENT KINDS OF WATER.*

In the ordinary process of boiling water in a kettle, most of the accompanying phenomena escape our attention; but if a thin glass vessel be used it is noticed, as the first effect of the heat, that bubbles of gas arise from the bottom and ascend through the liquid. This is due to the fact that gases are more soluble in cold liquids than in hot, and the first gases to be liberated are oxygen and nitrogen, derived from atmospheric air which has dissolved in the water. As the liquid gets hotter, bubbles of steam will form on the lower surface in contact with the flame, will rise a short distance and then be condensed and collapse with a crackling noise, which, echoed by the metal, is the cause of the "singing" of a kettle. These bubbles will rise higher and higher as the heat increases, till at last they rise to the top, the steam escapes, and the liquid is said to boil. It will be seen that steam itself is absolutely transparent, and only becomes visible when it condenses to a cloud of minute particles of water. Thus the moisture in the air is invisible until it condenses on a cold surface as dew, or is naturally chilled into mists or clouds. Whenever, then, the steam impinges on a cold surface, it changes again to