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(THE INTERNATIONAL SCIENTIFIC SERIES)

MICROBES

FERMENTS AND MOULDS

BY

E. L. TROUESSART

WITH ONE HUNDRED AND SEVEN ILLUSTRATIONS

NEW YORK
D. APPLETON AND COMPANY
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1890

PREFACE.

THE number of works which treat of microbes is already considerable, but they have all been written for a special public of physicians or naturalists, and imply that the reader is familiar with the ideas already established on pathology or on cryptogamic botany.

Although the science of microbes is of recent origin, it has made immense progress in the course of a few years. It is, moreover, essentially a French science, since it is owing to Pasteur's admirable labours, as well as to his solid genius, aided by the faith and energy of his disciples, that this science has been able to overcome the prejudices of ages, and to penetrate into the very heart of the ancient theory of medicine, so as to transform and regenerate it.

Every one now speaks of microbes, yet few of those who make use of the term have any clear conception of the beings in question, or could give an exact account of the function which microbes fulfil in nature. And yet this function concerns us all.

The man of the world who desires to take part in a scientific discussion; the lawyer who has to treat of a question of hygiene in the presence of experts; the engineer, the architect, the manufacturer, the agriculturist, the administrator—all have to consider such questions, and they will find in this work clear and precise notions on microbes, notions which they would find it difficult to glean from books designed for physicians and professional botanists.

The questions of practical hygiene, those which concern domestic economy, agriculture, and manufactures, and which are connected with the study of microbes, must especially demand attention. These are pertinent questions in such a book as this. There is a certain danger in vulgarizing notions of medicine, strictly so called; but it can only be beneficial to make every one acquainted with the precepts of hygiene, which cannot become popular until they have penetrated into the habits and routine of national life.

There is much to be done before modern society is practically on a level with the achievements of science; many prejudices must be uprooted, and many false notions must be replaced by those which are sounder and more just.

For this reason, we have endeavoured to make this work intelligible to all. It may be read with profit by those who possess the elementary notions of natural science which are included in the course of primary instruction. We therefore hope that the volume may find a place in the libraries of secondary instruction, and in public libraries.

Although the work is not specially intended for physicians, yet practical men may not be indisposed to glance at it: it may, at any rate, serve as an introduction to the much more learned works of Cornil and Babès, of Duclaux, Klein, Koch, Sternberg, etc. We have given an important place to the botanical question, which is too often neglected in works on microbian pathology. From this point of view, the narrow bond which connects bacteria with ferments and moulds has to some extent marked out the plan we have adopted; namely, that of passing from the known to the unknown, from what is visible with the naked eye to that which is only visible with the aid of the microscope.

Angers, *September* 10, 1885.

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MICROBES, FERMENTS, AND MOULDS.

INTRODUCTION.

MICROBES AND PROTISTA.

MICROBES are the most minute living things which the microscope permits us to see distinctly, so as to study their organization. They are for the most part invisible to the naked eye, and even by the aid of a simple lens. In order to form an exact idea of their forms and structure, we require the strongest magnifiers of modern instruments, which enlarge the object 500, 1000, and even 1500 diameters.

The word *microbe* has been recently introduced into the French language; it did not exist eight years ago, and for this reason it will be sought for in vain in most dictionaries. It was under the following circumstances that this term, now in such general use, was invented by Sédillot, an eminent surgeon, whose recent death is deplored by France.

Those naturalists who have studied the most minute living things have at all times been at a loss to decide whether they have had to do with animals or plants. There can be no such doubt when we compare a tree of which the roots are fastened in the soil with a quadruped which moves freely on its surface. But these are highly developed forms, the one in the vegetable, the other in the animal kingdom. The lower representatives of the two kingdoms are, on the other hand, often so much alike as to baffle the most experienced naturalist. The animals which are assigned to the order of Zoophyta, or animal-plants, have, as the name indicates, a form which led them to be for a long while regarded as plants; many of them are fastened to the bottom of the sea or to rocks as if by actual roots, and, when superficially examined, their movements do not differ much from those which may be produced in true plants, as, for instance, in the mimosa.

Many of the lower plants, belonging to the groups of Algæ and Fungi, live in the water without being fixed by roots; many are animated by more or less apparent motion, at any rate during part of their existence, so that it is often somewhat difficult to distinguish them under the microscope from those beings which are generally called *Infusoria*, and which are true animals.

Hence it follows that the boundary between the animal and vegetable kingdoms remains indefinite, and that many of those microscopic organisms which we have now to consider, may be assigned indifferently to one or the other kingdom.

Bory de Saint-Vincent, a naturalist belonging to the early part of the century, and after him Hæckel, have attempted to evade this difficulty by creating between the animal and vegetable kingdoms an intermediate kingdom, which they have named Protista, indicating thereby that it includes the first animals which in the geological ages appeared on the earth's surface. This kingdom of Protista includes the following groups, starting from the simplest and going on to those which are more complex:—

*1. Monera (or Microbes, strictly so called; Schizomycetes, Bacteria, Vibriones, etc.).
2. Amorphous Rhizopoda (or Amœbæ).
3 Gregarinidæ.
4. Flagellata.
5. Catallacta.
6. Infusoria.
7. Acinetæ.
8. Labyrinthulæ.
9. Diatomaceæ.
*10. Myxomycetes.
*11. Fungi.
12. Thalamophora (Foraminifera or Rhizopoda with a calcareous skeleton).
13. Radiolaria (or Rhizopoda with a silicious skeleton).

The groups marked with an asterisk are those which we propose to study in this work. For the most part, the organisms assigned to them resemble plants in their general characters. They are parasites which derive their nutriment from other living beings.

For this reason, many of these organisms are the cause of the more or less serious diseases which affect animals or plants. Naturalists who regard these parasites as animals have termed them *Microzoaria* (from two Greek words signifying small animals). Those who regard them as plants have called them *Microphyta* (small plants), and it is still disputed which term is the most applicable to them. In other words, it is still undecided whether they should be classed in the animal or vegetable kingdom.

It was at the Paris Academy of the Sciences, on the 11th of March, 1878, that Sédillot took part in one of the probably interminable discussions between the advocates of the Microzoaria and those of the Microphyta, and he suggested, with the critical sense for which he was distinguished, the word microbe, to which it appeared to him that every one could give their assent.

In fact, the word microbe, which only signifies a small living being, decides nothing as to the animal or vegetable nature of the beings in question.* It has been adopted by Pasteur, and approved by Littré, whose competence to decide on neologisms is generally admitted; it has been in common use in France for the last four or five years, and may now be regarded as definitively adopted into the French language.

This word has not yet been fully introduced into

* Béchamp terms microbes *microzyma*, or small ferments, since the chemical reactions which result from their vital activity are generally fermentations.

the English and German languages. In order to indicate the organisms which produce diseases, they make use of the word *Bacteria*, which is only the name of one of the peculiar species assigned to this group, and the one with which we have been longest acquainted. In this case, the name is generalized and applied to an entire group.

The Italian authors who have been recently occupied with the study of microbes have on their part adopted the name *Protista*, proposed by Hæckel, and of which the sense, although not the etymology, is almost the same as that of the word microbe.

In reply to the question whether there is any real advantage in establishing an intermediate kingdom of Protista between the two organic kingdoms of animals and plants, we must answer in the negative. This third organic kingdom only serves to render the structure of our modern classification more complex; and it includes, as may be seen from the list given above, a collection of very heterogeneous groups, which it would be more simple to leave in one or the other kingdom. We should, in our opinion, approximate more closely to Nature's plan by only admitting two great kingdoms: the organic kingdom, which includes plants and animals; and the inorganic kingdom of minerals. The organic kingdom should then be divided into two sub-kingdoms, animals and plants, of which microbes or protista, or whatever else they may be called, should form the connecting link, and testify to the common origin of the two great organic kingdoms.

However this may be, we shall make use of the word "microbe" as the general designation of all the minute organized beings which are found on the borderland between animals and plants. We shall presently show that in the majority of cases these beings may be regarded as true plants, and this is at present generally admitted by most naturalists.

Part played by Microbes in Nature.—The part played by microbes in nature is an important one. We find them everywhere; every species of plant has its special parasites, and this is also the case with our cultivated plants—with the vine, for example, which is attacked by more than a hundred different kinds. These microscopic fungi have their use in the general economy of nature; they are nourished at the expense of organic substances when in a state of putrefaction, and reduce their complex constituents into those which are simpler—into the soluble mineral substances which return to the soil from which the plants are derived, and thus serve afresh for the nourishment of similar plants. In this way they clear the surface of the earth from dead bodies and fæcal matter; from all the dead and useless substances which are the refuse of life, and thus they unite animals and plants in an endless chain. All our fermented liquors, wine, beer, vinegar, etc., are artificially produced by the species of microbes called ferments; they also cause bread to rise, and from this point of view they are profitable in industry and commerce.

But in addition to these useful microbes, there are others which are injurious to us, while they fulfil the physiological destiny marked out for them by nature. Such are the microbes which produce diseases in wine; most of the changes in alimentary and industrial substances; and, finally, a large number of the diseases to which men and domestic animals are subject. The germs of these diseases, which are only the spores or seeds of these microbes, float in the air we breathe and in the water we drink, and thus penetrate into the interior of our bodies.

Hence we see the importance of becoming acquainted with these microbes. Their study concerns the agriculturist, the manufacturer, the physician, the professor of hygiene, and, indeed, we may say that it concerns all, whatever our profession or social position may be, since there is not a single day, nor a single instant, of our lives in which we cannot be said to come in contact with microbes. They are, in fact, the invisible agents of life and death, and this will appear more plainly from the special study we are about to make of the more important among them.

Since it is easier to know and observe beings which are visible to the naked eye, we shall first speak of fungi—that is, of the larger microbes, with whose habits and organization we are also best acquainted.

We will then go on to the study of the more minute ferments; and finally to that of bacteria (*Schizophyta* or *Schizomycetes*), which are, strictly speaking, microbes, and which only become visible with the aid of the microscope.

CHAPTER I.

PARASITIC FUNGI AND MOULDS.

I. General Remarks on Fungi.

Every one is acquainted with the field and forced mushrooms, two varieties of one and the same species, wild or cultivated, and often seen at table. It is less generally known that the truffle is also a fungus; and that the large class of fungi includes moulds and many parasites which are more or less microscopic, which live at the expense of wild and cultivated plants, and attack animals and also the human subject.

Fungi are among the lower plants, and differ from higher orders in their mode of life. It is well known that the large majority of plants are not nourished only by absorbing the mineral salts which, in a state of solution, their roots derive from the soil, but also, and chiefly, by decomposing the carbonic acid of the air, assimilating the carbon which, as cellulose, enters into the composition of all their tissues, and giving forth pure oxygen to the air.

This function is not, as it was formerly erroneously supposed, a respiration in the inverse form from that of animals. All plants without exception breathe like animals by absorbing oxygen. The assimilation of carbon is a true nutrition, and as the decomposition of the carbonic acid gas which results from this assimilation sets free a much larger quantity of oxygen than the plant requires for itself, it was for a long while believed that plants really breathed the carbonic acid gas of the air, in the inverse method to that of animals.

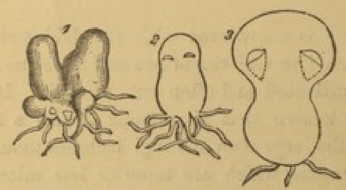

Fig. 1.—*Agaricus* in different stages of development: 2, 3, a vertical section showing the formation of the head. The hyphæ of the mycelium are shown in the lower part of the figure.

The assimilation of carbon is effected by the leaves and green parts of plants; the green, granular substance termed chlorophyll, which solely gives them this colour, as may be shown by the microscope, and which alone subserves this function of nutrition. Fungi, however, have no leaves nor other green parts; that is, they have no chlorophyl. They derive the cellulose which they contain, as well as all the substances by which they are nourished, either from other plants, or from animals and from the organic substances which are decomposing in the soil, such as dung and dead bodies. So that it may be said of fungi, that they subsist like animals by devouring plants or other animals; not like higher plants, which derive their nutriment from the soil or the air, and owe nothing to other living beings.

It is for this reason that some naturalists have regarded fungi as animals, and have classed them in the animal kingdom. We have seen that Hæckel and the naturalists of his school have assigned them to the kingdom of *Protista*. But setting aside their mode of nutrition, which is likewise found in plants of a higher organization, such as the *Orobrancheæ* and some of the *Orchidaceæ*, fungi really exhibit all the characters of plants, and as such we shall here consider them, although they are plants of a peculiar and very low type.

The class of fungi may be defined by saying that they are plants devoid of stems, leaves, and roots; that they consist only of cells in juxtaposition, devoid of chlorophyl. They never bear a true flower, and are simply reproduced by means of very minute bodies, generally formed of a single cell, which is called a spore, and which represents the seed.

In fungi of the highest type, such as that commonly known as the edible mushroom, the part which we eat and call the umbrella represents the flower or floral peduncle of other plants, and is in reality only the support or covering of the spores, which are fixed on the radiating lamellæ that may be seen on inverting the umbrella (Figs. 2 and 3). This umbrella or floral peduncle is the only part of the plant which appears above the soil, or the organic substances on which the fungus grows.

But the really essential part of the plant is that

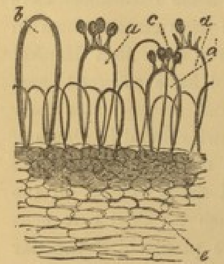

Fig. 2.—Section of one of the lamellæ of the umbrella of *Agaricus c*: *a*, *b*, spores of the *hymenium* (slightly magnified).

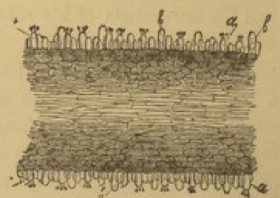

Fig. 3.—Spores of the *hymenium*, greatly magnified, and resting on their supports or *basides*, *a*.

which does not appear on the surface; namely, the white filaments or *hyphæ* which creep along the soil, the manure, or whatever supplies the nutritive matter, and which represent at once the root, the stem, and the branches of the plant; this part is termed the *mycelium*. We shall presently see that many of the lower fungi are without the organ we have called the umbrella, and which botanists term the hymenium or organ of reproduction, and consequently consist only of mycelium.

In this case, the spores or seeds are developed in the cells of the mycelium itself.

This latter mode of reproduction also occurs in the higher fungi, which therefore possess two modes of reproduction and two kinds of spores: exogenous spores, which are externally developed, as we see on the hymenium (Fig. 2); and endogenous or internal spores, which are developed in the mycelium (Fig. 4). These spores not only differ in the site of their origin, but also in their form, size, structure, and in the end they fulfil in the reproduction of the fungus. There are in many cases several forms of exogenous spores.

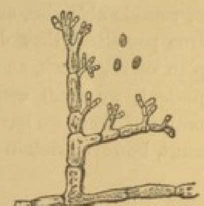

Fig. 4.—Endogenous spores from the mycelium of *Agaricus* (much magnified).

Classification of Fungi.—The nature of the spores, and the very varied mode of reproduction, have led to the classification of fungi in a certain number of groups, of which we need only cite the most important, and those which chiefly concern our present point of view. Such are—

1. The *Hymenomycetes.*
2. The *Basidiomycetes.*
3. The *Ascomycetes.*
4. The *Oomycetes.*

Each of these groups is subdivided into several sections or families. Ferments and *Schizomycetes,* or microbes, properly so called, are still often assigned to the class of fungi. We shall speak of them separately, and give our reasons for distinguishing them from true fungi.

Hymenomycetes are the fungi which possess the hymenium or umbrella; all the edible species are included in this class, together with a great number of extremely poisonous species. They are generally of considerable size, and only a few among them are true parasites; they do not, therefore, enter into the plan of this work, and, in spite of the interest they present, we shall content ourselves with the brief notice of them we have just given. The other groups must, however, detain us longer.

II. THE BASIDIOMYCETES: UREDINEÆ, THE RUST OF WHEAT AND GRASSES.

The name of cereal *rust* is given to a parasitic affection caused by a minute microscopic fungus which is developed on the leaves of wild and cultivated grasses. This rust appears in the form of orange patches, which gradually spread over the blades of wheat and other grasses, and its common name is due to this colour. Many of the plants belonging to other families are attacked by analogous parasites, and these fungi are all assigned by naturalists to the genus *Uredo,* and to the family of the *Basidiomycetes* or *Uredineæ.*

Basidiomycetes have no endogenous spores, but they may have as many as four forms of exogenous spores. This is the case with the rust of wheat, termed by naturalists *Uredo* or *Puccinia graminis*, which appears in the spring on the blades of this plant. The patches of rust are covered with a fine dust, which, under the microscope, is seen to consist of small elongated bodies of a reddish brown, resting on a filament; these are the first spores of the fungus, and are termed *uredospores* (Fig. 5). If they are scattered over a blade of wheat which was previously healthy, they germinate by means of a hypha of mycelium, which penetrates the leaf and develops a fresh patch of rust. In harvest-time the patches are of a darker, almost black shade, owing to the development of a second kind of spore. These are pear-shaped, divided in two, with an enveloping membrane of considerable thickness; they are called *teleutospores* (Fig. 5).

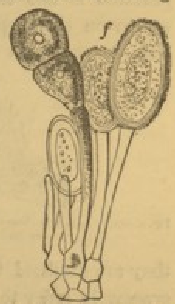

Fig. 5.—Part of a patch of *Puccinia graminis*, taken from a blade of wheat, and displaying several *uredospores* and one *teleutospore* (much magnified).

Teleutospores cannot germinate on a healthy blade of wheat, and consequently do not communicate rust. They may remain through the winter on thatch or wheat straw, awaiting the ensuing spring, and even then they cannot be developed upon a blade of wheat, but only upon the leaves of another plant, the barberry.

Borne by the dew or by a drop of rain on to the young leaves of the barberry, the teleutospores germinate, and form reddish-brown patches which affect both sides of the leaf. On its lower surface the spores are smaller, and are termed *spermata;* their function is not thoroughly understood. The larger spores on the upper surface are called *œcidiospores* (Fig. 6), and with these we are more concerned, since

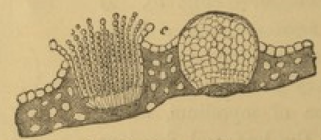

Fig. 6.—Section of a barberry-leaf bearing two œcidiospores, more or less developed, of *Puccinia graminis* (much magnified).

they are destined to return to the wheat, rye, or other grasses, in order to reproduce the original rust.

When they are placed on a blade of one or other of these grasses, the œcidiospores germinate at once, and it is soon covered with patches resembling those of the preceding year; when these patches are numerous, they dry up the blade and destroy the ear.

Hay and straw affected by rust should never be given to animals as food, since such food may produce disease.

Thus it appears that *Puccinia graminis* presents the phenomenon of alternation of generations; that is, the complete development of the fungus is only effected by its transference from one plant to another. This phenomenon may be frequently observed in animal and vegetable parasites, and it seems to be designed in order to secure the preservation of the parasitic species, by permitting it to grow on two plants in succession, of which the development occurs at different periods of the year; such is the case with the barberry, which is developed in early spring, while wheat is developed in summer. For a long while it was believed that *Œcidium berberidis*, *Uredo linearis*, and *Puccinia graminis* were so many distinct species; but it is now known, as we have stated, that they are only three successive phases of the development of a single species.*

Other *Uredineæ*, constituting the modern varieties of *Ustilago* and *Tilletia*, are more apt to affect the ears of wheat and other grasses. This disease is termed by agriculturists smut or *caries* (*Uredo carbo* or *Ustilago segetum*, and *Tilletia caries*). The diseased grain merely appears to be of a somewhat darker colour, but on pressing it between the fingers, there issues from it a blackish, oily pulp, which smells like rotten fish. Bread made from the flour of such corn has an acrid and bitter taste, and although it does not appear to be directly injurious to health,

* So, again, *Œcidium rhamni* (Nerprun or Bourdaine) produce *Uredo rubigo-vera* and *Puccinia coronata* of wheat and oats. (See Fig. 7.)

it cannot be regarded as fit for food. The dust arising from these fungi often produces in threshers in a barn an irritating cough, which ceases when they are no longer subject to the exciting cause.

The *verdet*, or, as the Italians call it, *verderame* of maize is due to the presence of the same parasite (*Ustilago segetum, Uredo carbo*, or *Sporisorium maïdis*) on the grains of maize, and for a long while it was believed to produce *pellagra*, a common disease among the peasants who live on maize. It is now known that pellagra is due to the growth of another fungus, much resembling the ergot of rye, of which we shall speak presently.

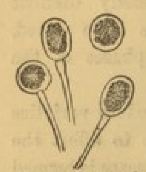

Fig. 7.—Spores of *Uredo rubigo vera*, or *Puccinia coronata*.

Other species of *Uredineæ* attack sorghum, rice, etc., and, indeed, very many plants are affected by parasitic fungi belonging to the genus *Puccinia* and to allied genera, and it is probable that they almost all present the phenomenon of alternation of generations.

A simple means of freeing our fields from the rust of wheat is indicated by what we now know of the alternation of generations which ensures the propagation of this fungus. We must destroy all the barberry bushes which are found in the vicinity of cornfields. Popular opinion, although ignorant of the phenomenon of alternation of generations, has long regarded the neighbourhood of the barberry as the principal cause of the rust of cereals.

In 1869, De Taste ascertained that in the parish of Chambray, after the peasants had uprooted all the barberries which grew in the hedges, the harvest, which had been bad in the foregoing year, was gathered in under normal conditions for three successive years. After the Lyons Railway Company had planted a barberry hedge to fence the railway in the parish of Genlis (Côte-d'Or), the cornfields bordering on the line were attacked by rust in an aggravated form. An inquiry made by the company showed that the disease was due to the barberry, and that where that plant was not found, the wheat was not affected by rust. On the other hand, a single shrub of barberry caused the disease to appear in a field in which it had never occurred before.

The smut of wheat may be destroyed by the application of quicklime, either dry or dissolved in water, which destroys the fungus or checks its development. Seed corn should always be subjected to this operation when affected by smut. In default of quicklime, sulphate of copper is sometimes used, which may be injurious, or sulphate of soda, dissolved in water (eight kilograms to the hectolitre). This should be done the day before the seed is sown. In the case of corn intended for food, another process called *pelletage* must be employed; this consists in the frequent stirring of the granaried corn, either with the hand or with Vallery's movable granary floor, so as to dry and aërate it, and expel the dust and damp, which are favourable to the development of fungi.

III. Ascomycetes; Ergot of Rye; the Mould of Leather and Dried Fruits.

In distinction from the species just described, the fungi in this group possess endogenous spores, enclosed in a sac or special envelope which is called an *ascus*; hence the name of the family. Truffles, or *Tuberaceæ*, are only reproduced by the spores contained in these asci; but most of the other ascomycetes present in addition several forms of spores, and the phenomenon of alternation of generations has led to the belief that in this case, as in that of the foregoing group, many of the so-called species are only successive transformations of one and the same species. This is the case with the ergot of rye, a product used in medicine; it is, however, a serious and dangerous disease of several of our cereals, and particularly of rye (Fig. 8).

Ergot is caused by a minute parasitic fungus which attacks the ear of rye when it is in flower. The young flower is covered with a white mass, consisting of microscopic spores, formerly termed *sphacelium* (Fig. 9). These spores reproduce themselves on other flowers, and propagate the evil.

The mycelium formed by the germination of the sphacelium affects the grain, forms in it a thick felt-work, and is developed so as to constitute the elongated substance termed *sclerotis* (on account of its hardness), or ergot; it is called at this stage *Claviceps purpurea*.

The sphacelium surrounding it falls off, and until the

Fig. 8.—Ear of rye, on which there are several grains of ergot.

Fig. 9.—*Sphacelium* or *Claviceps purpurea*, the first stage of ergot (magnified).

Fig 10.—Ergot bearing the organs of fructification (magnified).

following spring the ergot remains stationary on the soil on which it has fallen.

In the spring, owing to the heat and moisture, the hyphæ of the sclerotis swell and send forth numerous branches, bearing at their extremity a sort of rounded head, in which the asci or *peritheces* are developed (Figs. 10, 11, 12); the endogenous spores issuing from these asci germinate on the rye-blossom, and produce there a fresh sphacelium, then a second ergot, thus always passing through the same cycle of alternation of generations.

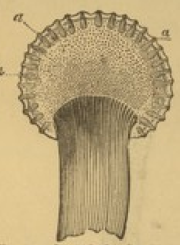

Fig. 11.—One of the heads or organs of fructification in ergot, still more magnified. *a*, peritheces.

Most of the *Graminaceæ* and several *Cyperaceæ* are capable of producing ergots resembling those of rye,

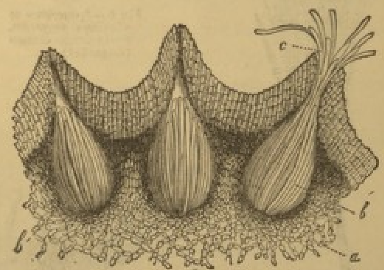

Fig. 12.—Portion of preceding figure under a very high magnifying power, showing at *b* the asci, and at *c* the spores issuing from the asci or peritheces.

and possessing the same medical properties. The suggestion has been made that instead of the ergot of rye the ergot of wheat should be used in medicine; it is larger, harder, and more elongated in form, and it also appears to be less perishable.

Ergot of rye, especially when powdered, strongly resembles meat in smell, and only becomes unpleasant when the powder is spoiled by being kept in a damp place; it then smells like rotten fish, and this is the case with many other fungi.

At first the taste is not very apparent, but it afterwards produces on the pharynx a somewhat persistent sense of constriction. The chief action of this drug consists in producing contraction of unstriated muscular fibres, especially those of the uterus. Ergotine and ergotinine are extracted from it, and these, which are its active principles, are often employed in therapeutics in preference to raw ergot.

In large doses ergot is a strong poison. It then produces characteristic symptoms, dilatation of the pupils, retardation of the circulation, vertigo, stupor, and even death.

Bread made with flour from which the ergot has not been extracted may produce the grave symptoms known as ergotism, and these soon become fatal unless the use of such bread is discontinued. Sometimes nervous symptoms predominate, and this is termed convulsive ergotism; sometimes the disease takes the form of gangrene of the extremities, or gangrenous ergotism, but these two forms are only two phases of one and the same disease, and often occur in the same individual. In countries where rye bread constitutes the chief food of the rural populations, as in Brabant, the north of France, Orléannais and Le Blaisois, fatal epidemics have been recorded at different times in the Middle Ages, under the name of St. Anthony's fire. The first symptoms are a species of intoxication, sought after by the peasants, and becoming habitual, like alcoholic drunkenness, up to the moment when convulsions and gangrene set in, and death soon follows.

Ergot of maize produces analogous phenomena. In countries where maize bread and cakes are in use, as in Italy and South America, it appears to be the cause of the disease improperly called *Pelade*. Of this the shedding of the hair and skin is the first symptom.* Fowls which feed on ergotized maize lay eggs which are devoid of shell, owing to their premature expulsion from the uterus; their combs become black, shrivel, and finally drop off; and they even shed their beaks. All these phenomena may be easily explained by the action of ergot on the muscular fibres of the uterus, and of the blood-vessels.

Recent research has shown that *Pelade* is identical in its cause and external symptoms with the disease known in northern Italy and in the south of France as *pellagra*, and in Spain as the rose sickness. The latter

* We shall presently see that the name *Pelade* was formerly given to another parasitic affection, peculiar to that part of the skin covered with hair. These two diseases must not be confounded, notwithstanding the similarity of name, since they are produced by two fungi belonging to different groups.

name is due to the red stains which cover the skin, afterwards drying up and falling off in the form of scales. At first the general health is not affected, and several years may intervene before the occurrence of vertigo, a want of appetite, emaciation, and finally the torpor and convulsions which precede death. These ill effects may be prevented by baking the maize before grinding it, according to the process in use in Burgundy.

There is another very common fungus also belonging to the group of ascomycetes, termed *Eurotium repens.* This mould appears upon leather which has been left in a damp place, and on vegetable or animal substances in process of decomposition or badly preserved, and especially upon cooked fruits.

This mould is of a sombre green, a colour by no means due to the presence of chlorophyl. On the mycelium, which spreads over the substance of the leather or of the fruit-skin, small stems are developed, consisting of a jointed tube, and terminating in an enlarged head on which chaplets of small grains are formed, each of which is a spore. This was formerly termed *Aspergillus glaucus,* and was regarded as a peculiar species (Fig. 13).

When, however, this mould is developed in a place in which the supply of air is limited, small gold-coloured balls may often be observed beside or in the midst of the stems, and these are filled with asci, each containing eight spores. This second form has been termed *Eurotium repens.* It has recently been ascertained that the balls in question are produced from the same mycelium as *Aspergillus glaucus*, and that consequently the chaplet of stalks and the balls filled with asci are merely two organs of the same fungus.

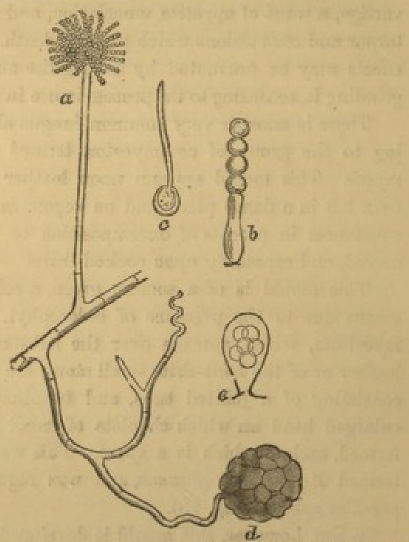

Fig. 13.—*Aspergillus glaucus*, mould on leather and rotten fruits: *a*, hypha bearing the chaplet of spores *b*; *c*, a germinating spore; *d*, ball of Eurotium; *e*, ascus enclosing the endogenous spores (magnified).

The chaplet of spores in *Aspergillus glaucus* represent the white exogenous spores, or the sphacelium of the ergot of rye, and those which are subsequently produced in the yellow balls correspond with those which issue from the asci developed on the sclerotis; these are endogenous spores.

Many of the parasitic fungi belonging to the genera *Erysiphe*, *Sphæria*, *Sordaria*, *Penicillium*, etc., present a similar mode of vegetation, and affect a large number of plants. Such is the *Oïdium* of the vine (*Erysiphe Tuckeri*) to which we shall presently revert.

IV. Oomycetes, Mucorineæ, or Moulds, properly so called; Peronosporeæ; the Potato-Fungus.

In all the parasitic fungi of which we have hitherto spoken there is no sexual reproduction analogous to that of the higher plants; there are no male and female organs comparable to the stamens and pistil. This sexual reproduction exists in the oomycetes, although only in a very elementary form. In addition to the ordinary spores which we have noticed in other fungi, there are others termed *oospores*, which are formed by the fusion of the originally distinct contents of two different cells. In the family of the mucorineæ, which includes most of the fungi commonly called *moulds* (Fig. 14), the two cells of which the contents are fused together are similar. In the peronosporeæ, however, which includes the potato-fungus, one of the

Fig. 14.—*Mucor caninus*, the mould on dog's excrement (magnified).

cells is larger than the other, and persists alone up to the moment when the oospore is mature. It must, therefore, be regarded as the female cell; while the

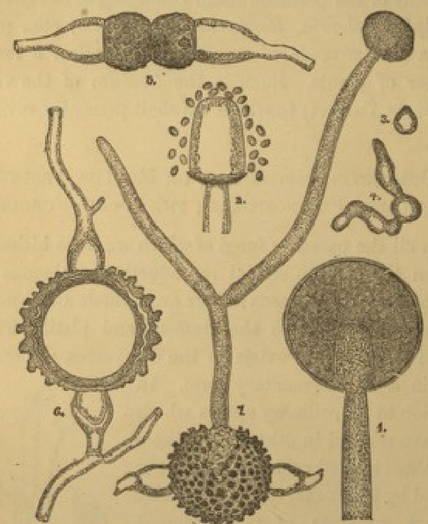

Fig. 15.—Reproductive organs of *Mucor mucedo* (much magnified).

other, which is smaller and soon withers away, is the male cell.

The mycelium of the oomycetes is developed in a more or less liquid medium, like all other decomposing and putrefying substances. The ordinary spores are very small, and are formed within a small enlargement (*sporangium*) borne on a free hypha of the mycelium. Their succession is constant and numerous as long as the plant is in a favourable medium in which it can flourish. The spores which are found in the same medium germinate, and reproduce a mycelium similar to that from which they had their origin.

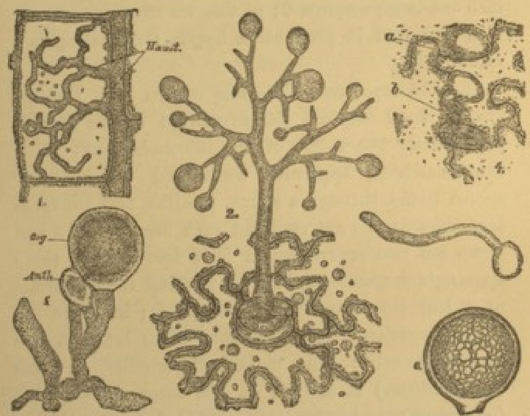

Fig. 16.—Reproductive organs of *Peronospora calotheca* (much magnified).

The oospores may be as much as a thousand times larger in volume than ordinary spores. They are only formed when the growth of the fungus is on the wane, as, for instance, when the substance serving as a support to the mycelium is drying off: a long period may elapse before they germinate (Figs. 15 and 16).

Fig. 15 represents the reproductive organs of *Mucor mucedo.* 1 is the sporangium filled with ordinary spores; in 2, the wall of the sporangium has disappeared, so as to show the free spores round the central columella; 3 and 4 represent the germination of these spores, giving forth their hyphæ; 5 gives the conjugation of the sexual spores, which are fused into one large oospore, 6; of this we see the germination in 7, and it produces a hypha terminating in a sporangium.

Fig. 16 represents the same organs in a *Peronospora.* In 1 we see the mycelium of the fungus penetrating the tissue of the infected plant; in 2, the fructifying apparatus containing the ordinary spores issues through a stoma, ramifies, and produces sporangia at the extremity of each branch; in 3 and 4 we see two spores which have issued from these sporangia germinating and penetrating the epidermis of a leaf through the stomata (*a*, *b*); in 5 we see the conjugation which has taken place between two dissimilar cells: the male cell, smaller in size (*antheridium*) is applied to the large female cells (*oogonium*), and after this mode of fertilization it is termed an oospore, which is represented in 6.

Mucor mucedo, and other species of the same genus, form the small downy tufts of a greyish white colour which may be observed on mouldy bread, rotten fruits, and on the excrement of horses, dogs, and rabbits. When examined under the microscope, the filaments of which these tufts consist display at their extremities the sporangia represented in Fig. 15, 1. On rotten fruits, the spores of these fungi germinate in five or six hours by introducing their hyphæ through the epidermis. *Sleepiness*, which is only the first stage of rottenness, is, according to Davaine, to be ascribed to the action of these fungi. Fruit in this mouldy condition is sometimes unwholesome.

The potato-fungus, *Peronospora infestans*, is one of the most dreaded scourges of this valuable plant. It attacks the lower surface of the leaves and stalks, and appears in the month of July, in the form of brown patches. The long hyphæ penetrate deeply beneath the epidermis, and will even propagate themselves on the tubers.

Among the causes which produce or promote this disease, agriculturists place the excessive moisture of the soil, setting the plants too late in the season, the use of bad seed, the premature and exhausting germination of the tubers before they are planted, and the use of fresh dung which is not sufficiently decomposed.

The following process is indicated as likely to prevent the development of this parasite. In the spring, the first protective ridge should be prepared with a flat top, from eight to ten centimetres high, and from twenty-five to thirty centimetres wide. In the first fortnight of August, a second protective ridge should be earthed up, of which the edge should be acutely sloped, and the stalks of the plant should be turned down into the furrow, so that any spores which may be on the leaves may be washed off them by the rain, and not come into contact with the stem and roots of the plant.

It is probable that earth-worms diffuse the spores of this fungus, as well of those of many other microbes.

According to Prillieux, beetroot is attacked by another species of *Peronospora*, which causes the leaves of the plant to wither and fall. The remedy consists in burning the dead leaves on which the oospores remain during the winter, or, at any rate, in not allowing them to be placed on the dung-heap.

The mildew which affects the vine is also a species of *Peronospora* (*P. viticola*) as we are about to show.

V. Parasitic Fungi of the Vine: Oïdium, Mildew, etc.

The parasites of the vine are so numerous as to require a separate chapter. Some years ago, in 1870, fifty of them were enumerated by Roumeguère, a well-known specialist, and the number is now more than doubled. We shall only now speak of the more important, of those which are especially injurious to the vine, and which consequently are the most interesting to us.

Oïdium. — Oïdium, or *Erysiphe Tuckeri* — so called from the name of the vine-grower by whom it was first described—has been longest known to us among these parasitic fungi. It belongs to the group of Ascomycetes, and appears to have reached us from America in 1845, in which year it was first observed in England. Thence it passed over to France. In 1847 it was noticed in the neighbourhood of Paris; and afterwards, in 1850-1851, in the south of France, where for twenty-five or thirty years it raged with such intensity as to threaten for some years the almost complete destruction of the vine-yards, a destruction which is now taking place under the attacks of another parasite, belonging in this instance to the animal kingdom: *Phylloxera vastatrix.*

The oïdium, the white disease or *meunier,* was equally destructive in the vineyards of Madeira, so that it was necessary to uproot all the vines, and replace them by sound plants which were incapable of bearing grapes for some years.

The oïdium appears on the grape in the form of greyish filaments, terminating in an enlarged head, which contains an agglomeration of spores, not free or in a chaplet, as in *Aspergillus* (Fig. 13). These spores escape as fine dust, diffuse themselves in the air, and spread the disease afar with extreme facility.

If a spore lodges on a vine-leaf under favourable conditions of moisture and warmth, it soon germinates, penetrates the epidermis by means of its hyphæ, and forms floury patches which send forth a peculiar musty smell.

The oïdium may remain latent on the vine-stock throughout the winter. In the spring it reappears in yellowish patches on the earliest leaves, on which it is rapidly propagated; the plant languishes, and the leaves become pale and, as it were, anæmic.

Very dry weather is unfavourable to oïdium, and so also are heavy rains, which wash the fruit and leaves, and carry away the spores on to the soil.

The remedy consists in the application of sulphur to the infected vines. Flowers of sulphur is used, which acts upon the fungus by gradually setting free sulphurous acid. Under this influence the microscope shows that the superficial mycelium and the fragile spores dry up as if they were burnt (Ed. André). Three successive applications are necessary, and these are made with the help of a special instrument in the form of a pair of bellows, to which a rose is affixed, in order to disseminate the flowers of sulphur. The first application is made in spring, when the shoots are from eight to ten centimetres long; the second directly after the vine has blossomed; and the third when the grapes begin to ripen. The operation in spring is the most important, and should be performed with the utmost care, so as to affect all the hybernating spores from which the succeeding generations would issue. Not only the upper and lower sides of the leaves must be dusted, but also the branches and the stock itself. The third application should be made early enough for the sulphur to have disappeared from the grapes before the vintage takes place. It is evident that its introduction into the wine would have the worst effect: in process of fermentation sulphuretted hydrogen would be given off, which is injurious to the alcohol, and this gas would give an unpleasant taste to the wine.

The morning is the best time for applying the sulphur, since the dew enables the powder to stick to the leaves and branches; and it should be made on a fine day, since heavy rain would carry off the sulphur before it has time to act upon the oïdium.

The sulphur which ultimately reaches the soil below the vine is transformed into sulphate of lime, which is an excellent dressing for the vine.

Mildew.—This new parasite, of which the scientific name is *Peronospora viticola*, belongs to the group of Oomycetes. It also comes to us from America. It was imported into Europe in 1878, with the American plants destined to replace those destroyed by the phylloxera, and was rapidly diffused through France, and thence to Algeria. It appears in the form of irregular patches of a whitish colour, not very thick, and with an almost crystalline appearance like that of a saline efflorescence (Planchon). It has not the mouldy smell of oïdium, and appears later in the season, generally on the autumn shoots. Its mycelium penetrates more deeply than that of oïdium. Brown patches appear on the upper surface of the leaf, as if it had been scorched; and in correspondence with these there is a delicate down "like the whiteness of a slight hoar-frost" (Vaissier) on its lower surface. The hyphæ issuing from the mycelium ramify at right angles, and these branches bear the spores, as in the potato-fungus, *Peronospora infestans* (Figs. 17, 18). These numerous spores, diffused through the air, are powerful sources of contagion.

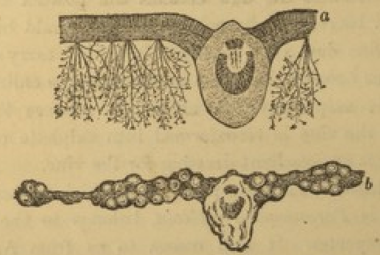

Fig. 17.—*Mildew*: *a*, vertical section of a leaf, bearing tufts of *Peronospora viticola* on its lower surface; *b*, a withered leaf, bearing the winter spores (*oospores*) (× 20 diam.).

This parasite destroys the tissue of the leaf, exhausts it, and finally causes it to wither and fall. Those which are least affected have only diseased patches. The bunch of grapes and the young herbaceous shoots are rarely affected.

In addition to the ordinary or summer spores of which we have spoken, the sexual spores must be noted; the oospores, or dormant winter spores, which hybernate in the tissue of the leaf itself (Fig. 17, *b*), and germinate in the spring. The conjugation of the sexual spores, as well as the ripening of the summer spores, and the germination of the zoospores which issue from them, can only occur in a drop of water, rain, dew, or mist, so that a persistent drought checks the propagation of this fungus.

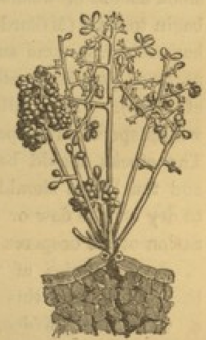

Fig. 18.—Group of tufts of *Peronospora infestans*, issuing from a stoma on the lower surface of the leaf and bearing the summer spores (× 120 diam.).

The parasite injures the stock by stripping it of its leaves, thus hindering the nutrition of the plant; moreover, the grapes, since they are imperfectly protected from the sun, dry up before they are ripe. Sometimes, also, the fungus attacks the grape itself, or its peduncle.

Vines planted in a moist soil resist its attacks better than others, simply because the nature of the soil makes the plant more vigorous, and suitable manure acts in the same way. When the fungus is developed, it may be destroyed by sulphur mixed with powdered lime. Since its mycelium is more deeply seated than that of oïdium, it is necessary to have recourse to more vigorous measures in order to reach it. Powdered borax has also been prescribed, in the proportion of five grammes to a litre of water; also a solution of sulphate of iron, one kilogram to two litres of water, with which the stock should be washed fifteen days before the shoots begin to start (Millardet). Mme. Ponsot, in Bordelais, has used the same substance mixed with lime (four parts of powdered sulphate of iron to twenty parts of lime). The fallen leaves which contain the winter spores, or oospores, should be burnt or buried. The stocks should be irrigated as often as possible, and the leaves should be dusted with lime in order to dry off the dew or mist, which favours the fertilization of the oospores.

Some species of vines resist the disease better than others, and this is the case with the Labernet, a vine from Médoc, which has remained almost entirely free from it in infected regions of Algeria.

Anthracnosis, or Black-rot.—This fungus, of which the name is *Phoma uvicola*, or *Sphaceloma ampelium*, belongs to the ascomycetes. Of all the parasites of the vine it was the earliest known, but it was only in 1878 that its devastations were important enough to attract attention. Like the two preceding fungi, it is reproduced by spores carried afar by the slightest breeze. Heat and moisture are favourable to its propagation, which is checked by drought.

It appears on the young shoots in the month of May, in the form of round black spots which gradually spread over the twigs, leaves, and grapes

The young stalks assume a sickly appearance, and often wither off, together with the leaves and fruit.

When the fungus fastens on the fibro-vascular bundles of the leaves before their complete development, the leaves shrivel and curl up, and perform their functions imperfectly; when it attacks the petiole or peduncle of the bunch of grapes, it dries up, and the destruction of all the parts in dependence on it soon follow. It is this fungus which, under the name of rot, now devastates the American vineyards.

Sulphur is by no means so efficacious in this case as it is with oïdium, but the following treatment is prescribed by Portes:—

1. The prunings of the vine and other remains of the preceding years should be destroyed. 2. The suckers and young shoots should be dusted, in the second fortnight of April, with slaked lime which has been finely powdered, and this operation should be repeated once a fortnight up to the end of June. 3. Sulphur should be applied at the usual times, especially if there is any oïdium. 4. The vines should be drained and irrigated as often as possible. 5. In all cases in which the fungus can be detected, powdered lime should be applied at the interval of some days, alternately with the same substance mixed with flowers of sulphur.

Aubernage, called by the Italians the *Black disease*, must not be confounded with Anthracnosis. According to recent researches, *aubernage* is not produced by a fungus, but by a degeneration which is either spontaneous or, as Pirotta and Cugini suggest, the work of bacteria, and which consists in the transformation of the cellulose and starch of the plant into dextrine, as Comes asserts, or, according to Pirotta, into tannin.

This disease appears in three stages: (1) a simple discolouration of the sap, which assumes a tawny black shade without checking vegetation; (2) a beginning of necrosis, which renders the plant unhealthy; (3) a complete necrosis, which affects the woody parts and arrests the growth of the plant.

This disease is contagious, which leads us to believe that if it is not produced by a fungus, it is at any rate due to the development of a bacterium—that is, of a microbe.

The remedy indicated by Italian naturalists consists in the application of salts of potassium, which may be extracted at small cost from the ashes of the vine branches which are burnt upon the spot.

Rœsleria hypogea, or Rot.—This parasitic fungus is found on the vine-roots, and has been recently studied by Prillieux. The vine affected by this parasite languishes for some years and then dies. The evil spreads by means of the roots to adjoining stocks, and the parts affected spread like the patches formed by the phylloxera. The roots rot away. This disease has been widely spread in Haute Marne.

This small fungus is distinct from one which bears the same French name, *Pourridié*, which is found in the south of France, and has been studied by Planchon and Millardet. These naturalists describe it as formed by the rhizomorphous mycelium of a large hymenomycetous fungus, *Agaricus melleus*. *Rœsleria* is very different. It is a small white fungus, with a white or ash-coloured head, from eight to ten millimètres in size, of which the mycelium lives in the interior of the vine-roots, penetrating and profoundly affecting all the tissues of the roots, and producing in the autumn the fructification which comes to the surface.

It is generally developed in marly and argillaceous soils, after a rainy season, and in the low-lying parts of vineyards on the slope of a hill. It thrives in the moisture which lies below the surface of the soil, and it is therefore important to improve the condition of those sub-soils which are impermeable.

It is also necessary to separate the stocks, so as to prevent their roots from interlacing, and to uproot and burn diseased vines, since the fungus may subsist for several years in dead and dried roots. If, which is almost always the case, any fragments of roots remain in the ground, they will reinfect the sound stocks which have been substituted for them.

Remarks on Diseases of the Vine.—We may be surprised that this valuable plant, which has been so carefully cultivated in France, should be attacked by such a number of parasites, both animal and vegetable. Yet we should rather be surprised that the vine has not been completely destroyed by the combination of such diverse scourges, and that it has effectually resisted them in several regions of France. When we consider that for long years the same hoary old stocks have been required to produce grapes without truce or mercy, and often without taking pains to supply to them by a fitting manure the nourishment which is withdrawn from them by the fructification of the grape, we shall be less astonished at the decadence of our vineyards. And, indeed, enlightened minds ascribe the attacks of these numerous parasites to the weakness and exhaustion of our vines, rather than to any accidental cause, such as an importation from without.

The principal remedy may, therefore, be found in restoring the strength of the vine by the planting of young suckers, and still more of seedlings. Instead of attempting to introduce foreign plants, which it may not be easy to acclimatize, and which will certainly be less valuable than the vines we have lost, it would surely be better to seek to regenerate our indigenous kinds by crossing the cultivated stocks with wild vines, or else, as Millardet suggests, by crossing them with each other. The attempt might also be made to graft the stocks from Bordeaux and Burgundy on wild or American vines, which offer a better resistance to the attacks of the phylloxera.

VI. Habitat of Parasitic Fungi: their Destructive Action.

The habitat of parasitic fungi is extremely varied. Roumeguère, in his *Cryptogamie illustrée*, has devoted more than forty pages of a large quarto, printed in three columns, merely to the enumeration of fungi, classified according to their position in plants, animals, organic or inorganic substances, and the author himself admits that this list is far from complete.

Parasitic fungi are found on plants belonging to all the families of the vegetable kingdom, and also on other fungi; on living animals, vertebrate and invertebrate; on their dead bodies and on excrement; in stagnant waters and in the sea, on piles and rocks. Others prefer marshes, turf-bogs, heathy ground (which may be marshy or dry), dunes, caves and holes, and even completely covered by the soil, as is the case with truffles. Others, again, grow upon stones, walls, and rocks; in the open air or in ruins; or, like *Torula conglutinata* and *Himantia cellaria*, in the darkest caves, where they form a species of feltwork, often several centimetres in thickness, of a blackish colour, ragged, and extremely light, which in the course of a few years overspreads the walls of cellars. Other fungi inhabit our houses, attack our food, clothes, utensils of every kind; wall-papers and books, of which the paste offers a nutriment which they can easily assimilate; linen; and even our toilet sponges, notwithstanding that they are in daily use. They may even be found on the most powerful chemical substances, on pastilles of sulphur, arsenical solutions, etc.

"The general belief," writes Roumeguère, "regards fungi as the result of decomposition. This belief is due to an imperfect acquaintance with the nature of these plants. Fungi are not only found on fragments of wood and decayed vegetables, but sometimes even on bare pebbles, on glass, on window-panes, on the lenses of microscopes, and on other polished surfaces. It must be supposed that fungi are able to extract the elements of nutrition even in such positions. *Coprins*, which have a surprising power of development, grow on amputated limbs. Young has recorded the appearance of a great number of these fungi, still in an imperfectly developed state, below the mattress on which a man was lying whose leg had been amputated. The bed was cleaned, and in nine or ten days the fungus reappeared in the same abundance as before. Targionni-Tozetti had previously observed a similar growth on the apparatus which surrounded a fractured limb in St. George's Hospital, Modena."

Berkeley states that immediately after the death of any vegetable substance, an army of fungi of various kinds is at hand to complete the work of decomposition. The soft tissues are rapidly reduced to a semi-fluid condition by the combined action of putrefaction and of these fungi. The hardest wood yields to the same agents, not indeed so quickly, yet much more rapidly than would be the case from the action of the constituents of the atmosphere alone. When a log of one of our finest trees is attacked by fungi, it soon becomes only a mass of rotten wood, of which the woody tissue has been traversed and destroyed by the mycelium. If the same log were merely subjected to the action of the weather, it might endure for half a century before becoming completely rotten.

Merulius destruens (or *M. lacrymans*) attacks beams and the other pieces of wood used in building, and rapidly destroys them. The administrators of the Canal du Midi, Toulouse, were compelled to replace the oak piles which protect the sides of the canal as it traverses the town, on account of the ravages of *Dematium giganteum*, one of the higher orders of fungi in its early form. At the end of the last century, the same fungus destroyed, in the course of two or three years, the *Foudroyant*, a sixty-gun vessel.

In order to stop the development of these fungi in wood used for building, and especially in wood intended for ship-building, it is expedient, as soon as the trees are felled, to steep them in a metallic antiseptic solution—as, for instance, in sulphate of copper.

An experiment made by Nägeli, a celebrated botanist in Munich, demonstrates the action of microscopic fungi on organic substances, exclusive of any previous deterioration.

"I enclosed," he says, "several loaves in a tin case, which was carefully but not hermetically closed. When the case was opened at the end of eighteen months, the loaves were reduced to a small mass, consisting almost entirely of filaments of mould, in which I could detect no trace of the substance of bread. This mass was soft and moist, like a mud-pie. It emitted a strong odour of trimethylamin: no trace of starch remained. One hundred parts in weight of the original bread were transformed into sixty-four parts in their moist state, and seventeen parts after desiccation in the open air. The starch had been consumed in order to form carbonic acid and water."

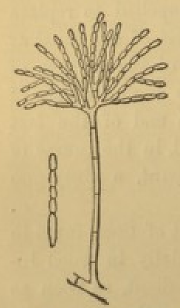

Fig. 19.—*Chætonium chartatum*, mould on paper.

Badham sums up in a few words the destructive effects of microscopic fungi. "*Mucor mucedo*," he writes, "devours our preserves; *Ascophora mucedo* turns our bread mouldy; *Molinia* is nourished at the expense of our fruits; *Mucor herbarium* destroys the herbaria of botanists; and *Chætonium chartatum* (*Actinospora*) develops itself on paper, on the insides of books, and on their binding, when they come in contact with a damp wall (Fig. 19). When beer or sweetmeats turn sour, it is the work of a fungus."

VII. Parasitic Fungi of Insects, regarded as Allies of Man.

Many microscopic fungi attack insects, both living and dead. We have all seen the bodies of flies still sticking to the window-pane or curtain, and surrounded by a species of aureole formed by the growth of a fungus, *Penicillium racemosum*, or sometimes *Sporendonema muscæ* or *Saprolegnia ferax*, of the family of Oospores (Figs. 20, 21, 22).

Fig. 20.—Body of a fly, surrounded by an aureole of *Saprolegnia ferax*.

Cordiceps attacks certain caterpillars of the genera *Cossus* and *Hepialus*, when they are buried in the sand before their metamorphosis into chrysalides, and kills them by the development of its mycelium in their tissue. These caterpillars may often be found, bearing on their backs a fungus longer than themselves (Fig. 23).

Sphæria militaris, a parasite to *Bombyx pityocarpa*, the caterpillar found on pine-trees, represents one of the few fungi which may be regarded as beneficial to man, since it destroys multitudes of these caterpillars, and thus neutralizes the ravages caused by their devouring the young shoots and pine needles.

In the Antilles there is a wasp called the vegetable wasp, because it is attacked during its lifetime by a fungus which it carries about for some time, and which finally causes its death: this is *Torrubia spherocephala* (Tulasne). *Isaria sphingum*, another

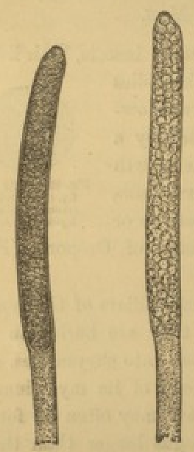

Fig. 21.—Two filaments of *Saprolegnia* containing spores (greatly magnified).

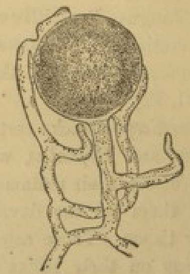

Fig. 22.—Oogonium of Saprolegnia surrounded by Antheridia (much magnified).

species of the same genus, has been observed on the back of a butterfly, which was poised upon a leaf as if alive, and which was probably killed by the development of the fungus.

These and other facts, not to speak of the muscardine of silkworms, to which we shall return, have given rise to a surmise that if we could discover the parasitic fungus of the phylloxera, we might transform it into a powerful auxiliary of agriculture, since by its aid the parasitic insect which now ravages our vineyards might be destroyed.


Fig. 23.—Butterfly-nymph bearing a *Cordiceps.*

From this point of view Giard has observed several of these parasites of insects, which he calls *Entomophthoreæ,* from the name of their principal genus, *Entomophthora.* Such is *E. rimosa,* which attacks grasshoppers and the diptera of the genus *Chironomus,* enveloping them in a thick feltwork formed by the winter spores, and speedily killing them. In the same manner *Isaria pulveracea* attacks *Pyrrhocoris apterus,* an insect which is often injurious to our kitchen gardens.

It has been asked whether *Entomophthora Planchoni,* the parasite of the aphis, might not also prey upon the phylloxera, but the experiments made in this direction have not hitherto been so successful as to allow us to count on this means of averting the scourge. With the same object, Hagen has suggested the use of beer-yeast, which seems to have a destructive effect on insects, as it is developed in their tissues.

VIII. Muscardine, the Disease of Silkworms.

Muscardine, which is caused by a true fungus, *Botrytis bassiana*, must not be confounded with other diseases which attack the silkworm, such, for instance, as pebrin, which, as Pasteur asserts, is caused by a bacterium, or, strictly speaking, a microbe, and, according to the recent researches of Balbiani, by *Psorospermia*. We shall presently revert to this disease.

Botrytis bassiana is a true mould, belonging to the group of Oomycetes, and allied to the potato-fungus, *Peronospora*. It is propagated by spores, which, when falling on a silkworm, germinate and penetrate its body. A mycelium is then developed, which may take possession of the whole caterpillar without appearing externally. The germination is rapid in proportion to the age of the silkworm.

When death has been caused by the development of the mycelium, hyphæ appear through the animal's skin; these soon bear white, chalky spores, which are readily detached and float in the air in impalpable dust like smoke. The silkworms on which the dust falls do not appear to be diseased, and eat with avidity, but they die suddenly. It takes from 70 to 140 hours to develop the spores and spread the contagion. It is difficult to free the breeding-houses from all the silkworms which die in this manner; those which die after having crawled up to the heather to prepare for their transformation into chrysalides are only thrown away when they are found on removing the cocoons. The clouds of dust dispersed by the silkworms perpetuate the disease in the best-ordered factories. When the heather is thrown out of window, and the rooms are swept to get rid of the dust, the spores float in the air and are dispersed by the wind.

Damp favours the development of the fungus, and the introduction of healthy silkworms into an infected breeding-house will not extirpate the disease. In order to attain this object, it is necessary to get rid of all the dead silkworms before the development of the spores, and to destroy their bodies by burning them with the heather, or with quicklime. The breeding-houses should then be completely emptied, and the compartments should be purified and disinfected in the ordinary way by fumigation with sulphur, and washed with chlorine water, before fresh silkworms are placed in them.

IX. Parasitic Fungi of the Skin and Mucous Membrane of Men and Animals.

The skin-diseases of man and animals which are termed *tinea* are caused by the presence of parasitic fungi, just as the itch is produced by the presence of animals belonging to the group *Acarus*. These diseases are rendered eminently contagious by the dissemination of the spores of these fungi, which will germinate wherever the conditions of heat and moisture are favourable, even on a healthy skin, or where it is only irritated by a simple scratch.

Ringworm, Achorion Schœnlenii, the fungus which produces this disease on the parts of the skin covered by hair, belongs to the same family as oïdium. Its mycelium produces hyphæ, bearing chaplets of spores, as in the Mucorineæ, but there is no true sporangium.

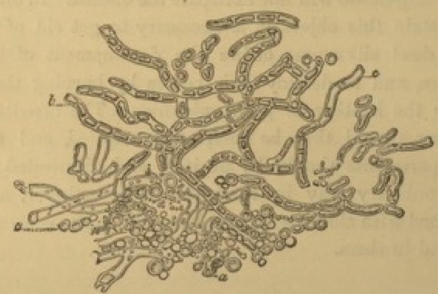

Fig. 24.—*Achorion Schœnlenii*, fungus of ringworm (× 400 diam.): *a*, spores; *b*, chains of spores; *c*, mycelium.

They are found in abundance in spots of ringworm, amidst the sulphur-coloured substance which carpets them. If a morsel of this substance is dissolved in ammonia, the fungus is detached, and may be observed under the microscope, especially if care has been taken to stain it brown by an aqueous solution of iodine (Fig. 24).

The mycelium consists of elongated, cylindrical articulations, which find their way among the cells of the epidermis, especially in the vicinity of the edges of the patch, and may penetrate deeply into the dermis (Fig. 25). Some of the shorter filaments terminate in

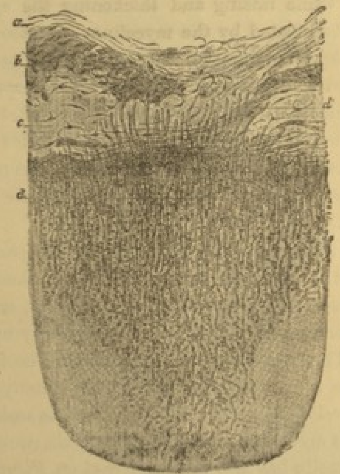

Fig. 25.—Transverse section of skin, on the level of a spot of ringworm: *a*, epidermis; *b*, superficial layer of dermis; *c*, deep layer of the dermis; *d d'* mycelium with spores.

chaplets of spores, which are successively detached from the stem; they are therefore found detached in large numbers in the midst of the epidermic cells. The centre of the patch is occupied by one or more still infected hairs, surrounded by spores; but, while the centre is in process of healing, the fungus extends to the periphery and continues to spread. The raised surface of the patch is formed by this parasitic growth, which forms a circular excrescence, always increasing in size, while raising and thickening the epidermis. The parts affected by the mycelium are characterized by a slight suppuration throughout the patch; the indurated tissue is gradually absorbed, leaving deep scars which persist after a cure has been effected.

The mycelium is found on infected hairs between the coats of their bulbous roots, while the numerous spores are only found between the epidermic layers of the hair.

This fungus may be inoculated in all parts of the skin, but its favourite site is the head, where it produces the disease long known as ringworm, or *favus*.

It has been already said that fungi prey upon each other. Thus *Achorion* has for a parasite *Puccinia favi*, a minute fungus of a reddish-brown colour, which is often developed on the whitish epidermic scales which cover the mycelium on fresh spots of ringworm. The same parasite has also been observed on *Pityriasis*.

Trichophyton tonsurans.—This fungus, allied to the preceding, subsists likewise on skin covered with hair, and produces *tinea tonsurans*.

It is formed of a mycelium with two sorts of hyphæ, some simply nutritive, others with short articulations, separating into chaplets of rounded spores, which are continually detached (Fig. 26). The

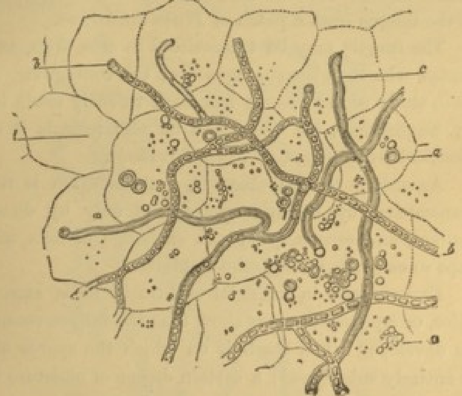

Fig. 26.—*Trichophyton tonsurans* on the epidermic layers of a patch of circinnate herpes: *a*, spores; *b*, mycelium with long articulations; *c*, mycelium with short articulations (× 400 diam.).

mycelium is often ramified, and penetrates within the epidermic cells, especially at the base of the hairs.

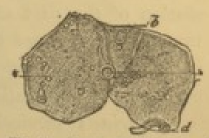

Fig. 27.—Spores and filaments of *Trichophyton*, germinating on two epidermic cells of the skin.

It is probably that the parasitic *Sycosis* which affects the beard, and circinnate herpes, two other skin-diseases, are only varieties of the same disease. In fact, Cornil and Ranvier have ascertained that if *Trichophyton* is inserted in the glabrous chin of a child, it will produce herpes; and that parasitic herpes may also be produced on the back of the hand by the transference of the fungus from a patch of *Tinea tonsurans*.

The fungus may be transmitted to cats, dogs, and horses, who thus become agents of the contagion. A fresh study of the disease has been recently made by an Englishman, Dr. Thin, and he also regards it as identical with herpes, or *Tinea circinata*.

According to this observer, the contagion is not transmitted by floating spores, but only by direct contact, and especially by the exchange of hats and caps so common among school-children.

Experiments in artificial culture in milk, carrot-juice, or aqueous humour show that the fungus cannot be developed when the hair on which the spores are is entirely submerged; a certain degree of moisture is, however, necessary, which is probably more frequently found on children's heads. In adults, the bulbous root of the hair is dryer between the follicle and the skin. The parasite may be destroyed by causing an inflammation of the part affected, since the serous effusion thus produced places the hair in the same conditions as in the culture-liquids in which it is completely covered, and not floating.

Pityriasis versicolor is produced by a fungus resembling the foregoing, termed *Microsporon furfur*. It grows between the cells of the epidermis, and effects their rapid degeneration. The hyphæ have long articulations, intermixed with round spores, not arranged in a chaplet, but grouped below the epidermis (Fig. 28). The development is very slow,

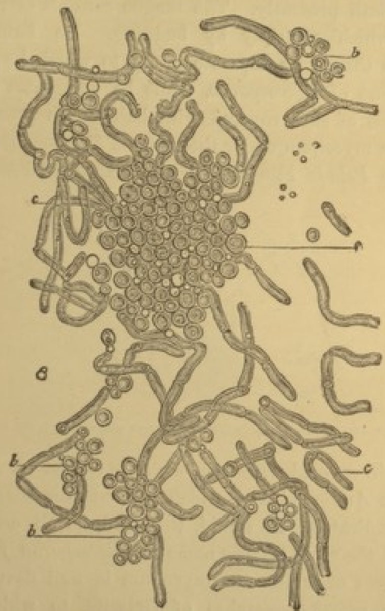

Fig. 28.—*Microsporon furfur*: *a*, *b*, groups of spores; *c*, mycelium with long, transparent, and curved articulations.

but the fact of its inoculation can be established, and artificial cultures may be made.

In the two parasites of which we have now to speak we cannot recognize any mycelium, and in this particular they are allied with the ferments, of which we shall speak presently. The fungus consists of round cells, which multiply by budding. De Lanessan regards them as a separate group, to which he gives the name of *Microsporeæ*, while he designates those parasites of skin covered with hair which possess a distinct mycelium under the name of *Trichophyta*.

The Pelade Fungus.—Pelade is another disease of

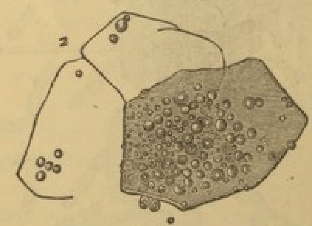

Fig. 29.—Pelade fungus: epidermic cells, charged with spores (× 500 diam.).

the skin covered with hair, which is caused by *Microsporon Audouini*, and which presents the characters just indicated. It would, therefore, be an error to give it the same generic name as *Microsporon furfur*, a fungus of which the mycelium is well developed, if the recent researches of Grawitz, to which we shall presently return,* did not tend to snow that Microsporeæ and Trichophyta are only forms of the same parasite in different phases.

* See chapter on Polymorphism of Microbes.

The pelade fungus develops in the superficial horny layer of the epidermis, on the surface of the epidermic cells, and in their interstices. It does not penetrate the hair-follicles, and is only occasionally found on the hairs, in which case it is fastened to the detached pellicles of the epidermis, not to the interior

Fig. 30.—Hair affected by the rapid progress of *Pelade décalvante*. It is surrounded by epidermic cells charged with spores (× 208 diam.).

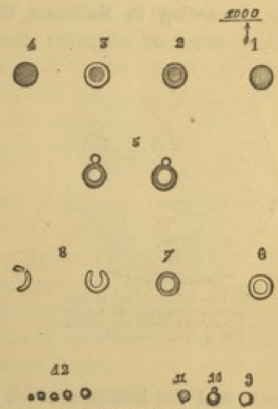

Fig. 31.—Isolated spores, taken from patches of pelade: 1, 2, 3, 4, large spores; 5, budding spores; 6, 7, 8, empty spores; 9 to 12, small spores (× 1000 diam.).

of the hair (Figs. 29, 30). It is composed entirely of the round spores already described, which are reproduced by budding (Fig. 31).

The Fungus of Pityriasis capitis simplex.—It is very similar to the foregoing, and is likewise seated in the horny layer of the epidermis, on which it produces a roughness in the form of dusty pellicles. It penetrates the hair-follicles, but not deeply, and only in the vicinity of the point at which they emerge. The spores of which it entirely consists are generally of an elongated form, and give off buds.

According to Mallassez, this fungus is the principal cause of *alopecia;* that is, the shedding of

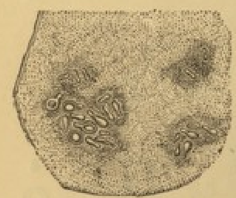

Fig. 32.—Epidermic cell of skin covered with hair, affected by *Pityriasis simplex*, and covered with spores (× 1000 diam.).

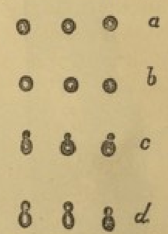

Fig. 33.—Isolated spores, taken from pellicles of *Pityriasis capitis simplex*: *a*, full spores; *b*, empty spores; *c*, full spores budding; *d*, the same empty (× 1000 diam.)

hair, and the baldness which eventually ensues from it. It acts in two ways: (1) its presence and multiplication disintegrate the epithelial layers; (2) the foreign body irritates the epidermis, producing excessive activity in the evolution of cells, and consequently the incessant desquamation which is the most apparent symptom of the disease. The shedding of hair is chiefly due to obstruction in that portion of the hair-follicle which underlies the orifice of the sebaceous glands, and this checks the regular development of the hair. The consequent irritation of the follicle produces hypertrophy; this leads to the shrinking and finally to the obliteration of the follicle, and after languishing for a while, the hair falls off.

Thrush (*Oïdium albicans*).*—This fungus generally appears on the mucous membrane of the mouths of infants, especially of those brought up by hand, and which have been accustomed to the use of a sucker. The saliva becomes acid, and the white spots which constitute thrush (Fig. 34) appear in several places, especially on the tongue, the gums, and the soft palate.

This plant is composed of two elements: of hyphæ, and of spores, which adhere closely to the mucous membrane. The spores become elongated and converted into hyphæ, which are segmented and ramified as their length increases; and they produce spores by division of the terminal cell, or sometimes by endogenous formation within the hyphæ.

Thrush sometimes occurs in adults in certain diseases, such as phthisis and typhoid fever, especially when the patient eats little and is imperfectly nourished, which is frequently the case in serious or protracted illness.

It is easy to destroy thrush by washing the mouth with Vichy water, or a solution of bicarbonate

* *Oïdium albicans*, Robin; *Saccharomyces albicans*, Rees; *Sacch. mycoderma*, Grawitz. (See chapter on the Polymorphism of Microbes.)

of soda, which neutralizes the acidity of the saliva. It is, above all, essential that the feeding-bottle, all the utensils employed for the infant, and the infant itself, should be kept perfectly clean; and, unfortunately, this condition is too rarely fulfilled, especially

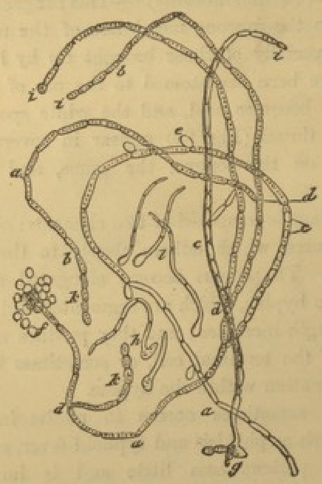

Fig. 34.—*Oidium albicans*, or *Saccharomyces mycoderma*: *d*, much-branched mycelium; *g*, chaplet or *torula* of spores, giving birth at *f*, *k* to the mycelium.

among the working classes in towns, and districts in which children are usually put out to nurse. The feeding-bottle in use in such cases generally smells so sour as to be offensive to every one who is not accustomed to it, and under these conditions thrush is almost certainly developed, so that few children escape an attack. It is not generally dangerous, yet it may, in some cases, compromise the health, and even cause the death of the child. In addition to care about cleanliness, a little pinch of bicarbonate of soda may be put in the feeding-bottle; this prevents the milk from turning sour.

Onychomycosis.—This disease, which attacks the nails of men and the hoofs of uni-ungulates (the horse, the ass, and the mule), is caused by a parasitic fungus of the genus Achorion (*A. keratophagus*). In man it is termed *dry caries*, and it is a fungus which is readily transferred from man to the animals with which he has to do, just as *Achorion Schœnlenii* of ringworm passes from man to the dog, cat, rat, horse, ox, and perhaps even to rabbits and gallinaceæ.

In uni-ungulates the fungus is introduced into the cracked and superficial layer of the hoof through its fissures. In order to destroy it, this external layer must be removed, and for greater security an anti-parasitic treatment should be used.

This remedy cannot be applied to the human subject without causing considerable pain; yet the nail may be pared and scraped, and the anti-parasitic remedy can then be applied.

Prevention and Cure of Skin-diseases.—The general custom of going to a common barber to have the hair dressed or cut must conduce to the dissemination of the fungi which attack those parts of the skin clothed with hair; the brush, the comb, or razor which passes successively and on the same day over hundreds of heads or chins must necessarily, if only in one case out of ten, carry the spores of the parasite from one person to another.

The parasitic diseases of the hair are extremely persistent, and precautions as to cleanliness will not always effect a cure. The mixtures sold by hairdressers under the name of capillary water, lotion to eradicate scurf, etc., should all be rejected. Experience shows that wetting the head often favours the development of the fungus, which may, indeed, remain stationary for two or three days, but which becomes more vigorous as soon as the head is dry. Sulphur and its compounds are successful in such cases, as well as in the parasitic diseases of plants. It would be best to apply this remedy in the form of a dry, impalpable powder, as in the application of sulphur to the vine, but this cannot be done without inconveniences to which the persons affected do not readily submit; it might, however, be tried by those whose hair is naturally greasy. In other cases, and especially in those in which the hair is dry, as it usually is in persons affected by *Pityriasis capitis*, pomades must be used, although it has been asserted, but not proved, that fatty substances afford nourishment to the fungus.

However this may be, the pomade for which we subjoin the recipe has been very successful in pityriasis, and in all the infantile forms of ringworm, including that which occurs in teething, and which may be safely treated, in spite of prejudices to the contrary:

Turbith mineral (tri-mercuric sulphate) ...	1 to 2 grs.
Benzoinated lard	15 grs.

This pomade is lemon-coloured; it will assume a flesh-colour by the addition of a few drops of red litmus, and may be scented to the taste of the person who is to make use of it. In ordinary cases of pityriasis, it need only be applied every eight or fifteen days. It is indispensable to wash the combs and brushes in a solution of potash or ammonia, lest the benefit of the treatment should be lost by re-infection. In the case of true ringworm, especially in adults, a much more energetic treatment is necessary, for which medical advice is required.

CHAPTER II.

FERMENTS AND ARTIFICIAL FERMENTATIONS.

I. What is Fermentation?

Chemists define fermentation in these words: "Fermentation takes place wherever an organic compound undergoes changes of composition, under the influence of a nitrogenous organic substance called a *ferment*, which acts in small quantities and yields nothing to the fermented substance" (A. Gautier).

This nitrogenous substance, termed a ferment, is regarded by naturalists as an organized living being, either animal or vegetable. This was demonstrated by the researches of Cagnard de La Tour, of Turpin, of Dumas, and more recently by the splendid achievements of Pasteur. It is now proved that the artificial fermentation which takes place in the manufacture of wine, beer, etc., is produced by small microscopic plants, called ferments or yeast.

The chemical transformation resulting from them might be obtained without the intervention of yeast, properly so called, either by means of a nitrogenous substance of animal origin (Berthelot), or by other chemical and physical processes which we shall presently mention. But it may be questioned whether the nitrogenous substance of animal origin, which Berthelot considers to be dead, does not contain a living ferment. This is not admitted to be the case by Béchamp, whose theory will be given further on.

Whenever fermentation is produced solely by the influence of physical and chemical agents, the action is very slow. But it is, on the other hand, very rapid when effected by living ferments or yeast, and it is also much less costly, so that the latter mode of fermentation is preferred by manufacturers. Yeast is, therefore, the true agent in artificial fermentations.

All the saccharine liquids which contain glucose or grape sugar, or a sugar which can be transformed into glucose, and also all nitrogenous substances, phosphates, and ammoniacal salts, produce alcohol at a temperature varying between 25° and 100°, and the yeast of beer (of which the spores are carried through the air) appears and is developed at the same time; this occurs in the juice of grapes, beetroot, sugar-cane, etc. The alcoholic liquids thus produced are then subjected to distillation in order to extract the alcohol. The transformation of alcohol into vinegar is produced by another ferment.

Fermentations are very common in nature. The transformation of sugar into lactic, butyric, and caproic acids, under the influence of nitrogenous substances and of the air; the change into glucose of gums, of starch, of dextrine, of sucrose, and mannite; the transformation of these substances into each other under the influence of living agents, or of those belonging to a living organism; the transformation of such glucosides as populin, salicin, tannin, etc., into sugar, or into neutral or acid substances;—all these phenomena are fermentations (A. Gautier).

We may even go further. The germination of seeds and the ripening of fruit are accompanied by phenomena of the same order. In animals, gastric, pancreatic, and intestinal digestion, together with other changes connected with nutrition and assimilation which take place in the blood and in all the organs, may be considered as true fermentations. In this case the cells of our tissues and the blood-corpuscles play the part of yeast in effecting alcoholic fermentations.

Finally, the miasmatic, virulent, and contagious diseases, which we shall study in another chapter, are also caused by changes in the blood and in the other fluids of the system, and should be considered as fermentations, produced by minute microscopic organisms analogous to ferments, and which are, as we shall presently show, bacteria or microbes, strictly so-called. The putrefaction of dead bodies is also a fermentation.

We shall, in this place, only consider the fermentations which are used in manufactures.

History.—The precise knowledge of the nature of fermentation is of comparatively recent date. The ancients, indeed, seem to have had an idea, however vague, of this phenomenon, which was in their case connected with the erroneous theory of spontaneous generation. We all know the fable of the bees, born from the putrefying body of a slain bull, which forms one of the chief episodes of the Metamorphoses of Ovid, and of the fourth book of Virgil's Georgics. Aristotle says that, by means of heat, one living being may have its birth in the corruption of another. . . . Fermentation is, in fact, always accompanied by an evolution of heat. The same idea was revived in the Middle Ages, and during the Renaissance by alchemists and physicians. Van Helmont, who lived early in the seventeenth century, goes so far as to say, "It is true that a ferment is sometimes so bold and enterprising as to form a living being. In this way, lice, maggots, and bugs, our associates in misery, have their birth, either within our bodies or in our excrement. You need only close up a vessel full of wheat with a dirty shirt, and you will see rats engendered in it, the strange product of the smell of wheat and of the animal ferment attached to the shirt."

Beside these singularly rash and purely fanciful assertions, which show that imagination was allowed in those days to play a much too important part in natural science, we find a theory of the fermentation in putrefying bodies which would not be rejected by modern naturalists and chemists.

"After death . . . the foreign ferments, which are always intent on change, are borne through the air and introduce corruption into dead matter . . . at least, unless the flesh is combined with certain substances, such as sugar, honey, or salt. It is, therefore, these ferments, attacking whatever matter is deprived of life, which disintegrate and prepare it to receive a new soul (or fresh life)."

Linnæus, again, says that "a certain number of diseases result from animated, invisible particles, which are dispersed through the air. . . ." Boerhave, in 1693, distinguished three kinds of fermentation: alcoholic, acetous, and putrefactive. But we must come down to the beginning of this century in order to find more definite ideas respecting the organic nature of ferments.

In 1813, a chemist called Astier asserted that every kind of germ from which ferments proceed is carried by the air; that this ferment, of animal nature, is alive, and is nourished at the expense of the sugar, and hence results disturbance of the equilibrium between the elements of sugar.

Subsequently, in 1837, Cagnard de La Tour declared yeast to be a collection of globules which are multiplied by budding; and in the following year Turpin described the yeast of beer as a vegetable, microscopic organism, which he termed *Torula cerevisiæ* (Fig. 35).

Chemists were at first unwilling to admit the important part played by yeast in fermentations, and in order to explain it, they assumed the existence of a very obscure physico-chemical phenomenon, to which the name of *catalysis*, or action by presence, was given. But in 1843 an illustrious French chemist, Dumas, clearly explained the physiological function of the living ferment, or yeast.

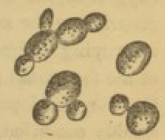

Fig. 35.—*Torula* (*Saccharomyces*) *cerevisiæ*, yeast of beer (× 400 diam.).

"Fermentations," he writes, "are always phenomena of the same order as those which characterize the regular accomplishment of the acts of animal life. They take possession of complex, organic substances, and unmake them suddenly or by degrees, restoring them to the inorganic state. Several successive fermentations are, indeed, often required to produce the total effect. The ferment appears to be an organized being; . . . the part played by the ferment is played by all animals, and by all but the green parts of plants. All these beings and organs consume organic substances, multiply and restore them to the simplest forms of inorganic chemistry."

Finally, Pasteur's memorable labours, which he began to publish in 1857, confirmed the new theory of fermentation, which no one now doubts. Pasteur states that every fermentation has its specific ferment; in all fermentations in which the presence of an organized ferment has been ascertained, that ferment is necessary. This minute being produces the transformation which constitutes fermentation by breathing the oxygen of the substance to be fermented, or by appropriating for an instant the whole substance, then destroying it by what may be termed the secretion of the fermented products. Three things are necessary for the development of the ferment: nitrogen in a soluble condition, phosphoric acid, and a hydrocarbon capable of fermentation (such as grape sugar). Finally, every organized ferment of fermentation or putrefaction is borne about in the air, as may be shown by experiments.

II. Vegetable Nature of Ferments or Yeast.

Yeast, or ferments, are in their organization closely allied to the fungi of which we spoke in the preceding chapter under the name of *Microsporon*. Many botanists still assign them to the class of fungi under the name of *Saccharomycetes*; yet, as they live in liquids, or at any rate on damp substances, like the Algæ, which are species of water-fungi, it is now almost agreed to place them in the same category as the latter, which they resemble in their whole organization, except in the absence of chlorophyl. This last characteristic, the only one by which they approximate to fungi, is common both to them and to microbes or bacteria, which are only ferments of smaller size, and which are now also placed in the class of Algæ. We shall return to this subject when we come to speak of bacteria.

The structure of ferments is very simple: each plant is generally composed of a single cell, spherical, elliptical, or cylindrical, formed of a thin cell-wall, containing a granular substance called protoplasm, which is the essential part of the plant. These cells have an average diameter of ten micro-millimetres. They grow and bud, and when one of them reaches a certain size, a median constriction occurs; it divides into two parts, resembling the mother cell, and these sometimes separate, sometimes remain united in a group or chaplet (Fig. 35). This mode of multiplication continues as long as the plant remains in a liquid favourable to its nutrition. But if its development is hindered, if, for example, the liquid dries up, the protoplasm contained in each cell contracts, and is transformed into one or more globules, which are the spores or endogenous reproductive organs of the plant. These spores may remain undeveloped for a long while, may become perfectly dry, and may even be subjected to a very high temperature, without losing the power of germination when they are again placed in conditions favourable to their development. They then reproduce the plant from which they had their birth, and are multiplied in the same manner.*

* For further details on ferments and fermentations, see Schutzenberger's work on the subject.

III. Wine Ferments; Alcoholic Fermentation.

The commonest ferment of wine is, according to Pasteur, *Saccharomyces ellipsoïdeus* (Figs. 36, 37, 38), which must not be confounded with Kutzing's *Cryptococcus vini*, since the latter has nothing to do

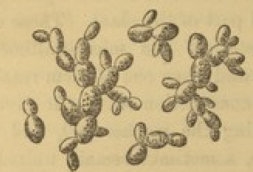

Fig. 36.—*Saccharomyces ellipsoïdeus*, wine ferment, in process of budding (×600 diam.).

with alcoholic fermentation. This ferment is found on the grape, and is thus introduced into the ferment-

Fig. 37.—*Sacch. ellipsoïdeus*: development of spores (× 400 diam.).

Fig. 38.—*Sacch. ellipsoïdeus*: germination of spores (× 400 diam.).

ing-vats. The adult cells are of an elliptic form, and are six micro-millimetres in length, by four or five in width. They bud, and are reproduced in the way already indicated, which is common to all ferments.

Sacch. Pastorianus (Rees) is probably only a variety of the foregoing (Fig. 39), differing a little in the form of the cells, which are elongated, pyriform, or club-shaped.

Lastly, *Sacch. conglomeratus* is somewhat rare. It is found in the grape-must when fermentation is nearly over (Fig. 40). It is so called because the new cells are conglomerated, instead of being arranged in a chaplet.

We must now notice the other ferments which

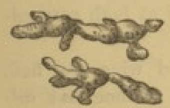

Fig. 39.—*Sacch. Pastorianus* (×400 diam.).

Fig. 40.—*Sacch. conglomeratus* (×600 diam.).

Fig. 41.—*Sacch. exiguus* (×350 diam.).

are found, like those given above, in fermented syrups, and which may also produce the alcoholic fermentation of wine. Such is *Sacch. exiguus* (Fig. 41), of which the cells are much smaller than in the foregoing, since they are only three micro-millimetres by two and a half micro-millimetres.

The apiculate ferment, of which Engel has made a separate genus, under the name of *Carpozyma apiculata*, is the alcoholic ferment which appears to be the most widely diffused in nature (Fig. 42). It is found on all kinds of fruit, especially upon berries and drupes, as well as upon most of the fruit-musts which are in process of fermentation. It has likewise been observed in Belgium upon beer. It is generally the first to appear and bud in the must. Its name is

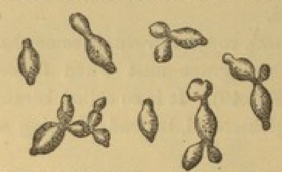

Fig. 42.—*Sacch. apiculata* (*Carpozyma*), ferment of fruits (×600 diam.).

due to the characteristic form of its cells, which are formed like rape-seed, or *apiculated* at both extremities of their large axis.

In the fermented must of red wine we find, together with *Sacch. ellipsoïdeus*, a somewhat different form, which is perhaps only a variety—*Sacch. Reesii.*

We must also mention another alcoholic ferment, *Sacch. mycoderma*, wine or beer flowers, which con-

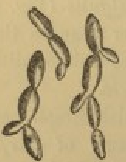

Fig. 43.—*Sacch. mycoderma*, or wine-flowers (× 350 diam.).

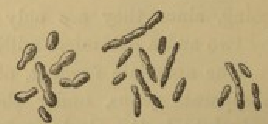

Fig. 44.—Different forms of *Sacch. mycoderma.*

stitute the white pellicle often seen on bottled wine (Figs. 43, 44). Pasteur has shown that, under certain circumstances, *Mycoderma vini* can produce alcoholic fermentation; this is easily shown by adding it to a saccharine solution, in which it soon produces fermentation. It appears on the surface of all alcoholic liquids which are exposed to the air, when fermentation is over or nearly over. Its growth is very rapid; a few cells are enough to cover the surface in the course of forty-eight hours with a thin white or yellow pellicle, which is at first smooth, and then wrinkled. This implies, according to Engel's estimate, that a single cell has produced 35,000 others in this short time.

Most of these different forms are probably only different stages of development of a limited number of species, since ferments are as polymorphic as microscopic fungi.

We have said that before they are found in the must of wine or fruits, the ferments fasten in a dormant state on the epidermis of the fruit, by which means they are introduced into the liquid about to be fermented. We see how the spores are transported through the air until they rest on the downy surface of a drupe or berry. But it has been asked what becomes of this ferment between last year's vintage and the succeeding summer, and in what way it passes the winter.

According to Hansen's researches, *Sacch. apiculata*, which is, for instance, found upon gooseberries, is washed off them by the rain, dispersed by the wind, and falls to the ground with the fruit, where it remains buried through the winter as a dormant spore, in order to return to the same fruit when it has ripened in summer. It can only be borne through the air when the ground is completely dried.

In the same way, the ferments of wine, after having passed through the bodies of men and animals, pass the winter on the dungheap. This revelation may not be pleasing to drunkards, but it will not surprise those who are acquainted with the habits of cryptogams in general, and of fungi in particular. Brefeld has found these ferments during the winter, especially in the excrement of herbivorous animals, and on the dungheap.

The manufacture of wine is too well known to require description; we need only remind our readers that alcoholic fermentation essentially consists in the transformation of glucose, or grape-sugar, into alcohol and carbonic acid. The latter, given off in the form of gas, produces the ebullition or effervescence which characterizes fermentation, and to which its name is due. Sugar or glucose is, therefore, the essential nutriment of all yeast-plants, and the indispensable element of these fermentations, of cider, beer, and all fermented liquors, as well as of wine.

IV. Beer-Yeast.

The yeast of beer, or *Sacch. cerevisiæ*, was the earliest known and the most carefully observed of all the ferments, and may be regarded as the type of the family. Its cells are round or oval, from eight to nine micro-millimetres in their longest diameter, isolated or united in pairs (Fig. 35).

When these cells are deposited in a saccharine liquid, which is therefore susceptible to fermentation, vesicular swellings, filled with protoplasm at the expense of the mother cell, may be observed at one

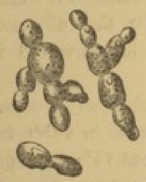

Fig. 45.—Yeast of superior beer budding (× 400 diam.).

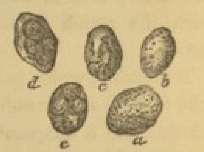

Fig. 46.—Spores of beer-yeast, in different phases of development.

or two parts of the surface of the cell; these swellings increase, acquire the size of the mother cell, and then contract at their base (Fig. 45). They generally arise on the sides of the cell, more rarely on its extremities. The new cells thus formed soon separate from the mother cell, and the protoplasm given up to its offspring by the latter is replaced by one or two empty spaces, termed *vacuoles*. When yeast is not in a liquid susceptible to fermentation, it can remain for a longer or shorter time without modification. If abruptly deprived of all nutriment, and especially of sugar, and placed in a sufficiently moist atmosphere, spores may be produced (Fig. 46). It is rather difficult to perform the experiment with success; the ferment must be frequently washed with distilled water, as it may otherwise putrefy, instead of fructifying (Schutzenberger).

Let us briefly describe the process by which the fermented liquor termed beer is obtained. The barley which constitutes its essential principle does not contain sugar; but when it has germinated it contains a substance termed *diastase*, under the influence of which the starch of barley can be converted into glucose.

The barley, which has been moistened in order to make it swell and germinate, is spread in a thin layer on hurdles, at a temperature of about 15°: this operation is called malting. It is generally performed in spring, in order to ensure the necessary warmth and moisture, and March beer is considered the best. When the sprout attains to two-thirds of the length of the grain, germination is arrested by drying the grains on a stove, and they are then ground to powder and become malt. This malt is then steeped in water at the temperature of 60° and by the action of the diastase the starch becomes glucose. This saccharine fluid or wort is boiled with hops, which are now added, not only to give a bitter and aromatic taste, but also to preserve it. This infusion of malt and hops is concentrated and cooled, and beer-yeast, the product of previous operations, is added in order to establish fermentation. The yeast is procured by collecting the scum of fermented beer and straining it into bags.

In Belgium, the wort is allowed to stand until the spontaneous development of fermentation takes place; but in France and Germany the ferment is generally added. In this case two methods are in use, fermentation from above, and fermentation from below; and this enables us to distinguish two kinds of yeast, that of superior, and that of inferior beer (Figs. 45, 47).

Fig. 47.—Yeast of inferior beer in process of budding (× 400 diam.).

In superior beer, the saccharification of the starch of malt is effected by successive steepings in casks at the relatively high temperature of from 15° to 18°. As the yeast is formed, it gradually issues from the bung-holes in the upper part of the cask; hence its name. In England, large open vats are used: the yeast rises to the top, and is removed with skimmers.

In the manufacture of inferior beer, saccharification is effected by steeping the malt in open vats at the lower temperature of from 12° to 14°. The yeast is deposited at the bottom of the vats in a doughy and tenacious mass. When the first and most active fermentation is at an end, the clear liquid is drawn off and put into casks, bottles, or pitchers, and as the separation of the yeast is not yet complete, it continues to act on the unmodified sugar. The production of fresh yeast makes the liquor thick, and the amount of alcohol and of carbonic acid increases in accordance with the time for which it is kept, after being bottled or put in closed casks.

The manufacture of most fermented liquors resembles that of wine or beer; that of cider is very simple, and consequently approximates to the manufacture of wine. The apples are cut and crushed, and remain in the vats until fermentation is over; the liquid is then separated from the solid residue, and put into casks or bottles.

V. Concerning some other Fermented Liquors.

There are many other fermented liquors made in various countries with substances derived from the animal or vegetable kingdom.

In France, cider or perry is sometimes made from pears or crab-apples.

What the French call *boissons* are cheap fermented liquors, prepared from dried raisins or aromatic substances, such as the dried fruit of the coriander, to which water sweetened with treacle is added. Fermentation is usually effected by germs borne by the air, or by those introduced by the coriander and the other ingredients of the liquor; or it may be hastened, as in Belgian beer, by the addition of beer-yeast or baker's yeast. It is effected by the transformation of the sugar into alcohol and carbonic acid, and this constitutes an aërated drink, which is very agreeable when well made, and especially if it has been carefully bottled before fermentation is over.

Koumiss is made of soured and fermented mare's milk, and is much used in Russia as a refreshing drink, from which an alcoholic liquor may be distilled.

Many kinds of brandy are made from the fruits and seeds of different plants. *Kirschwasser* is the alcohol produced by distilling cherries or geans; rum is made from sugar-cane, arrack from rice. Gin, distilled from the juniper-berry, is largely consumed by the labouring classes in England, as corn-brandy is in the French drinking-shops.

The savage Malay and Polynesian races prepare fermented liquors from the sap of various plants. Such is *kava*, made from masticated roots, and steeped in an infusion of *Piper methysticum*. In this case, the *ptzalin*, a ferment contained in the human saliva, transforms the fecula into a sugar susceptible to fermentation. The operators sit round a large vessel containing the roots steeped in water, and each man takes a piece, which he masticates conscientiously until it is sufficiently impregnated with the salivary ferment. This process is revolting to our ideas, and few Europeans would touch a liquor which has been prepared in such a way; but this is doubtless an educated prejudice which would not occur to a native of Oceana.

The dragon-trees (*Dracœna terminalis* and *D. Australis*) also possess a feculent root, from which a fermented liquor is extracted in the same manner by the Sandwich Islanders.

VI. The Leaven of Bread.

Bread is leavened in order to make it porous and more digestible. According to Engel, the microbe of baker's yeast is *Sacch. minor*, resembling that of beer-yeast, only more minute. Most of the yeasts which we have examined contain a great variety of microbes. However this may be, the fermentation of bread, like other fermentations, sets free carbonic acid gas, and this raises the dough and makes it light.

CHAPTER III.

MICROBES, STRICTLY SO CALLED, OR BACTERIA.

I. The Vegetable Nature of Microbes.

As we have seen in the preceding chapter, there is no well-defined limit between ferments and bacteria, any more than between ferments and fungi, or, again, between fungi and bacteria. Their smaller size is the principal difference which separates bacteria from ferments, since in other respects these two classes are for the most part alike in form and organization. There are bacteria of large size, such as *Leptothrix buccalis,* so frequently found in the mouth even of a healthy man, which much resembles in its mode of growth some of the lower fungi, such as *Oïdium albicans.* Yet the latter is regarded as a fungus, and the former as an alga, by our best cryptogamous botanists. It may, however, be said that the two classes of algæ and fungi are connected with each other by their lower forms, and probably have a common origin; just as the two great organic kingdoms are connected by their lower forms, which have been by some united in the kingdom Protista.

Microbes, or bacteria (*Schizophyta* or *Schizomycetes*), appear, in liquids examined under the microscope, as small cells of a spherical, oval, or cylindrical shape, sometimes detached, sometimes united in pairs, or in articulated chains and chaplets (Fig. 48). The diameter of the largest of these cells is two micro-millimetres, and that of the smallest is a fourth of that size, so that at least 500 of the former and 2000 of the latter must be placed end to end in order to attain the length of a millimetre. It is therefore plain that a magnifying power of 500 to 1000 diameters, or even still higher, is required to make these beings clearly visible under the microscope.

Fig. 48.—Ferment of vinegar (*Mycoderma aceti*), showing the different forms of bacteria, detached or in chaplets (highly magnified).

One very common bacterium may be found everywhere, and can be easily procured for microscopic observation: *Bacterium termo*, or the microbe of impure water. This bacterium is not injurious to health, since there is no potable water in which it is not found in greater or less quantity. In order to obtain numerous specimens, it is enough to take half a glass of ordinary water from a spring or river, and to leave it for some days on a table or chimney-piece, the vessel being uncovered to allow the access of air. We may soon observe that a thin coating is formed on the surface of the water, which looks like a deposit of fine dust; this dust consists of myriads of bacteria. If we take a drop of this water and place it under a cover-glass, in order to examine it under a microscope with a magnifying power of about 500 diameters, we shall, as soon as the instrument is properly focussed, see a really surprising spectacle.

The whole field of the microscope is in motion; hundreds of bacteria, resembling minute transparent worms, are swimming in every direction with an un-

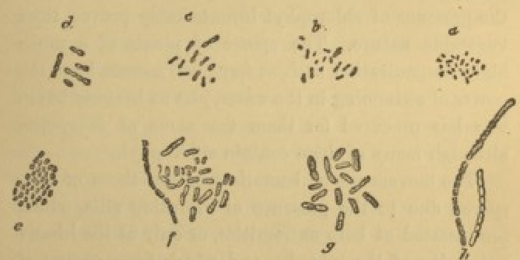

Fig. 49.—*Bact. termo* in different stages of development, *a–h* (much magnified).

dulatory motion like that of an eel or snake. Some are detached, others united in pairs, others in chains or chaplets or cylindrical rods which are partitioned or articulated (Fig. 49); these are only less mature or younger than the first. Finally, we see a multitude of small globules which result from the rupture of the chaplets. All these forms represent the different transformations of *Bacterium termo*, or the microbe of putrefaction. Those which are dead appear as small, rigid, and immovable rods.

In observing the lively movements of these minute organisms, we might be tempted to regard them as animals. But we know that movement, taken by itself, is not peculiar to the animal kingdom. Setting aside the movement which can be provoked in the mimosa and in many higher plants, it is well to remember that many of the lower plants are capable of motion: this is the case with *Diatomaceæ*, in which the presence of chlorophyl incontestably proves their vegetable nature. The spores of plants of a much higher organization, such as ferns and mosses, have the power of swimming in the water, just as bacteria have: this has procured for them the name of *Zoospores*, although many of them contain chlorophyl.

The movements of bacteria are, like those of zoospores, due to the presence of vibrating cilia, which are inserted at both extremities, or only at the hinder extremity of the microbe, and which form organs of propulsion analogous to the tails of tadpoles. These organs are very transparent and are difficult to see in the living subject, even with the strongest magnifying power, on account of the rapidity of their movements. But their existence has been ascertained by the use of staining fluids, and above all by micro-photography.

If, however, we analyze the mode of motion in *Bacterium termo*, and compare it with the movements of the ciliated or flagellated infusoria which may often be seen swimming with it in the field of the microscope, we are struck by the difference. Infusoria come and go, swiftly or slowly—they go back or move to the right or left; in a word, their movements seem to be actuated in some sense by *will*. Nothing like this is observed in the bacterium. The undulatory movement by which it is animated is always the same, and impels it straightforward, like a stone sent from a sling; it never voluntarily goes back nor out of its course, but only under the influence of a foreign impulse, such as contact with another bacterium, when it rebounds, just as a projectile may rebound from a wall. On encountering an obstacle, the bacterium remains indefinitely undulating before it, without ever pausing or showing signs of fatigue, until some external cause comes to release and send it to the right or left. We may often see a tangled mass of bacteria, perhaps adhering by their cilia or by some other substance, in which all the individuals continue to undulate until the rupture of the mass permits them to depart in all directions. These organisms are therefore plants in the character of their movements, as well as in the rest of their organization.

In bacteria each cell consists of a cellulose wall, containing protoplasm, as we saw was the case in ferments. The multiplication by fission is effected in precisely the same way in bacteria and ferments, and so also is the formation of spores. Under certain circumstances, when the liquid on which they subsist is dried up, the protoplasm contracts and forms spores, which, when set at liberty by the rupture of the cell-wall, germinate and give birth to fresh bacteria. The only difference consists in the fact that ferments may produce several spores in each cell, while bacteria never produce more than one.

Bacteria were, as we have already said, for a long while classed with fungi under the name *Schizomycetes.* But recent researches into their organization, and more especially into their mode of reproduction, show that they resemble a group of inferior algæ termed *Phycochromyceæ,* which includes *Oscillaria, Nostocs,* and *Chroococcus,* species generally furnished with chlorophyl. Bacteria represent a similar group devoid of chlorophyl. Zopf, in a treatise recently published, goes still further: he asserts that the same species of alga may at one time be presented in the form of a plant living freely in water or damp ground by means of chlorophyllaceous protoplasm, and at another in the form of a bacterium or parasitic microbe, devoid of chlorophyl, and nourished at the expense of organic substances which have been previously elaborated by animals or plants, thus accommodating itself, according to circumstances, to two very different modes of existence.

II. Classification of Microbes, or Bacteria.

It is very difficult to make any natural classification of the organisms which belong to the group of microbes; we have, in fact, seen that they only differ from each other in external form, and that these forms are very variable, since the same organism may present itself successively as an isolated globule, a chaplet, a chain, and a more or less articulated rod. Microbes are essentially polymorphous, and adapt themselves to varied conditions of existence, which influence the form taken by these microscopic organisms. For this reason their classification has often varied, their distinction into genera and species does not yet rely on precise data, and the opinions formed by various authors in accordance with their personal researches still differ widely.

We will, however, subjoin Wunsche's classification.

Schizophyta, or Schizomycetes.

A. Division of cells always occurring in the same direction, so as to form a chaplet before the joints or members separate.

1. Cells united in mucilaginous or gelatinous families.
   - *a.* Cells united (in a state of repose) in amorphous families.
     - α. Spherical or elliptic cells, colourless and generally motionless ... ... *Micrococcus.*
     - β. Cells elongated in short, movable rods ... *Bacterium.*
   - *b.* Cells united in families with sharp outlines, lobulated and agglutinated like frog-spawn ... *Ascococcus.*
2. Cells arranged in filaments.

a. Cylindrical filaments, indistinctly articulated, motionless.
- *α.* Unramified, very slender filaments:
  - (1) Short ... ... *Bacillus.*
  - (2) Long ... ... *Leptothrix.*
- *β.* Filaments repeatedly bifurcated (false ramifications) ... ... *Cladothrix.*

b. Spiral, movable filaments:
- (1) Short, faintly undulated ... ... *Spirochæte.*
- (2) Long, flexible ... ... *Vibrio.*
- (3) Short, rigid ... ... *Spirillum.*
- (4) Rolled into mucilaginous mass ... ... *Myconostoc*

B. Cells dividing cross-wise, and the daughter cells remaining united, like packets tied with a crossed cord ... ... *Sarcina.*

Most of the microbes of which we have now to speak may be assigned to one or other of the genera given in this scientific enumeration, and sometimes, on account of their polymorphism, to several of these genera.

Before making a more detailed study of some of them, it may be interesting to glance at them as a whole, following the order of classification given above.

The genus *Micrococcus* (Hallier) includes the spherical microbes, which are the most common and the most widely diffused, probably because the spores and early stages of all the other forms have this spherical shape before becoming elongated and assuming their adult form (Fig. 50).

Fig. 50.—Microbes under the form *Micrococcus* (much enlarged).

This genus is divided into two sections: the first includes *Micrococcus chromogenis, i.e.* fabricators of colouring matter—an extremely interesting group, on which we must say a few words, since these microbes play an important part in nature, connected with hygiene and domestic economy; the second section includes *Micrococcus pathogenis*, or the producers of disease, which must detain us longer.

The genus *Bacterium*, of which the name indicates that it is rod-shaped, also includes some coloured species and more which are colourless, such as the bacteria of putrefaction, of stagnant waters, of vegetable infusions, etc. (Fig. 49).

The genus *Ascococcus* is less common. The cells, united in groups or families, form mucilaginous, wrinkled membranes on the surface of putrefying liquids, on the juice of meat, on the infusion of hay, etc.

Bacillus (or *Bacteridiæ*, Davaine) forms an extremely important genus, characterized by its long, flexible, and articulated filaments; this genus includes the butyric ferment, and the microbe which produces the disease called *anthrax*, or splenic fever.

Leptothrix buccalis is found in the human saliva and between the teeth (Fig. 51, *k*).

Cladothrix dichotoma forms a kind of fine grass, which appears like a whitish mucilage on the surface of putrefying liquids (Fig. 51, *p*).

Vibrio rugula and *V. serpens* are found in infusions in the form of tolerably thick filaments, which have only one inflection, while their successors are spirally curved (Fig. 51, *l*).

Spirillum and *Spirochœte* only differ from each other in the number and approximation of their spirals. *Spirochœte Obermeieri* is found in the blood of those affected by recurrent fever; *S. plicatile*, which is found in stagnant water, amid *Oscillaria*, is

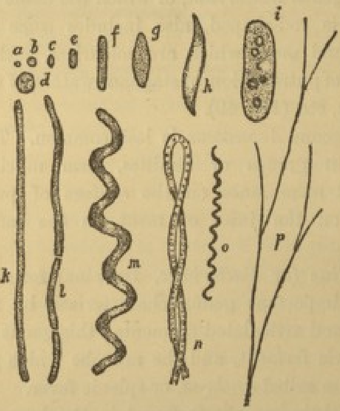

Fig. 51.—Different forms of microbes, or bacteria: *a*, *b*, *c*, *d*, *Micrococcus* of various forms; *e*, the short *Bacterium*; *f*, the short *Bacillus*; *k*, *Leptothrix* or long bacillus: *l*, *Vibrio*, dividing by fission; *m*, *Spirillum*; *o*, *Spirochœte*; *p*, *Cladothrix*, etc. (from Zopf: highly magnified).

perhaps only the parasitic form of those algæ, and has often been regarded as the cause of marsh fever. *Spirillum* is also found in infusions (Fig. 51, *m*, *o*).

Finally, *Sarcina ventriculi*, so different in form from other microbes, is found in the fluids of the human stomach, in the blood, and in the lungs, in the form of yellow patches. It is also found in the albumen of boiled eggs, in potatoes, etc. (Fig. 52).

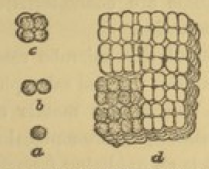

Fig. 52.—*Sarcina ventriculi*, in different degrees of development (strongly magnified).

III. The Microbe of Vinegar, and Acetic Fermentation.

Pasteur has shown that the acid fermentation of alcoholic liquids is due to the existence of a special microbe, acting like a ferment, which is developed on the surface of fermented liquors whenever they are abandoned to the contact of the air, in the presence of albuminoid substances. This microbe, which constitutes the *mother of vinegar*, and which is termed *Mycoderma aceti*, is probably identical with *Bacterium lineola*, so often present in infusions, in stagnant pools, and even in spring water. It is a true bacterium (Fig. 48).

The membrane which may be observed on the surface of liquids in course of acetic fermentation is formed of very minute elongated cells, from 1·5 to 3 micro-millimetres in length, united in the form of chains or curved rods. They multiply by the transverse fission of the cell, a fission preceded by a median constriction. These are characteristics of the bacterium, strictly so called.

The nutrition of this microbe resembles that of beer-yeast: it requires mineral salts, phosphates of the alkaline metals and of the metals of the alkaline earths, proteid matters, or ammoniacal salts.

This ferment is an oxidizing ferment, which withdraws oxygen from the air and transfers it to the alcohol, thus converting it into acetic acid; hence it can only subsist in contact with the air, and perishes when it is submerged, so that acetification is then arrested. The oxidizing power of this microbe is such that it can even oxidize alcohol and transform it into carbonic acid gas—a fact which explains how the strength of wine is lowered by the other and larger species, *Mycoderma vini*, of which we have given an illustration (Figs. 43, 44). This action is less lively in the presence of a considerable quantity of vinegar, and at Orleans acetification is always effected in vats which contain a large amount.

What is called the Orleans process, which is the one generally employed in France, consists in filling tuns which can hold about 200 litres with 100 litres of vinegar and 10 litres of white or red wine; once a week 10 litres of vinegar are drawn off, and replaced by 10 litres of wine. The temperature should be about 30°. Oxygen is supplied by a proper system of ventilation. This process is somewhat slow, since it only produces ten litres of vinegar out of each tun in the course of the week, and it has the disadvantage of encouraging the multiplication of *anguillidæ*, the small nematoid worms which live in vinegar and sour paste.

Pasteur has modified and improved the original process so as to obviate both inconveniences. He employs heat, which allows the process of acetification to be intermittent, and thus prevents the development of the *anguillidæ*. Shallow vats, about 30 centimetres in depth, with lids in which holes have been pierced, are used, and *mycoderma* is scattered on their surface. Gutta-percha tubes, pierced with holes at their lower extremity, are placed at the bottom of these vats, so that fresh liquid can be added without disturbing the superficial film of *mycoderma*.

In Germany, vinegar is made by means of spongy platinum, or platinum black, which oxidizes alcohol without the intervention of a microbe. This affords a good example of fermentation, or of an analogous phenomenon, produced solely by physico-chemical action. The platinum black acts by disintegrating the alcohol and placing it in more intimate contact with the oxgyen of the air, since the process of oxidation would be much slower without either this process or the presence of the ferment.

IV. The Microbes which affect Wine.

The affections to which some wines are subject alter their taste and quality so as often to render them unfit for use. These affections ought to be recognized, so that a diseased wine may not be confounded with one which is adulterated, and it is by means of the microscope that we are enabled to recognize the nature of these changes. Chaptal formerly ascribed them to the presence of an excess of ferment, since he was unable to discover any other cause. We now know from Pasteur's valuable researches, published in his book, *Études sur les vins*, that they are all due to the presence of microbes peculiar to each disease.

"The source of the diseases which affect wine," Pasteur writes, "consists in the presence of parasitic microscopic plants, which are found in wine under conditions favourable to its development, and which change its nature either by the withdrawal of what they take for their own nutriment, or still more by the formation of fresh products which are due to the multiplication of these parasites in the wine." These diseases are known under the names of *acescence*, *pousse*, *graisse*, *amertume*, etc. We shall review them in succession.

Mouldy or Flowered Wine.—These are wines on the surface of which white pellicles are formed (*fleurs de vin*), which consist of *Mycoderma vini* (Figs. 43, 53).

This product does not turn the wine sour, nor sensibly affect it. It is due to the temperature of the casks being too high during the hot season. It may be obviated by sprinkling them with cold water, or by putting ice into them; care must also be taken to keep the casks full, and the cellars as cool as possible.

Acidity of Wines; Soured Wines.—Wine always

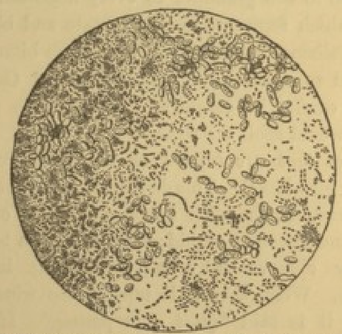

Fig. 53.—The disease *acescence*, which sours wine. Deposit seen in the microscope; 1, 1, *Mycoderma vini*; 2, 2, *Mycoderma aceti*, still young; 3, the same older, when the mischief is at an advanced stage.

contains a small quantity of acetic acid, and when this acid is in excess, the wine is no longer drinkable, and turns to vinegar. This change is due to the presence of *Mycoderma aceti* (Fig. 53), of which we have already spoken. It is much more minute than *M. vini*, and takes the form of the figure 8, as the illustration shows, or of chaplets formed by the union of several 8's placed end to end. As they grow older, the two globules of the 8 divide, and appear as isolated granules. These two species of *Mycoderma* are incompatible, and are never found in the same wine.

The acid may be isolated by distilling the sour wine. The attempt has been made to cure or improve sour wine by adding normal potassium tartrate (from 200 to 400 grammes to every hogshead of 230 litres), which forms potassium acetate and bitartrate by neutralizing the excess of acid. The bitartrate is deposited spontaneously, and crystallizes. Carbonate of lime cannot be employed for the same purpose, since it would spoil the wine.

Wines that are turned or over-fermented (vins poussés; vins bleus).—This disease displays the following characters: the wine assumes a bluish or brown colour, and becomes turbid; if shaken in a test-tube, we may observe silky waves floating in every direction. When a cask is tapped, the wine spurts up, and it is said *"qu'il a la pousse."* If poured into a glass, a number of minute bubbles appear on the surface, the discolouration increases, and the wine becomes more turbid. The taste is changed and becomes insipid, as if water had been added. The disease is developed in very hot weather (Chevalier and Baudrimont).

This affection is due to the presence of an extremely attenuated microbe, somewhat resembling that of lactic acid, which we shall describe presently, but differing from the latter in its undivided filaments. Its diameter is at the most one micro-millimetre: it varies in length, and is flexible, in which it resembles the genus *Vibrio*. These filaments collect in a mucous deposit at the bottom of the cask (Fig. 54).

Wine undergoes successive changes under the influence of this pathogenic ferment, and this has led

Fig. 54.—Wines affected by *pousse*. Deposit seen under the microscope: 1, ordinary alcoholic wine-ferment; 2, acicular crystals of potassium bitartrate; 3, crystals of normal calcium tartrate; 4, *Vibrio*, or microbe which produces the disease.

to the belief that there are several distinct diseases; hence the different names which have been given to this affection.

The remedies for the disease consist in the addition of tartaric acid; in drawing off the wine into sulphured casks, and adding a little brandy; and in taking care to keep the cellars whitewashed and airy.

Wine affected by Ropiness.—White wines, and especially champagne, are more often affected by this disease than red wines. It is more apt to attack wine which has little alcohol and is deficient in tannin, and under its influence the liquor becomes turbid, flat, and insipid, ropy, like white of egg, and it loses its sugar.

This change is effected by a filamentous microbe,

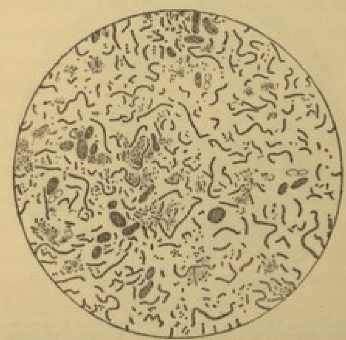

Fig. 55.—Disease of ropiness in wine, affecting champagne, and caused by a bacterium which assumes two forms: the figure 8, and chaplets.

even more like the lactic ferment (Fig. 58) than the one we have just described, since it is likewise formed of very minute globules, united in chaplets, which are, however, more attenuated than those of the lactic ferment. These filaments form a species of feltwork through which the liquid slowly filters; hence its oily appearance. It is probably a bacterium (Fig. 55).

This ferment may be destroyed by tannin (15 grammes to a hogshead), which has the effect of precipitating it. Very ripe sorbs, which have been crushed, may also be used for this purpose, as well as gall-nuts and grape-seeds which have been ground to powder; all substances rich in tannin. The precipitate thus formed should be separated from the wine by refining.

Wines affected by Bitterness.—This disease affects red wines, especially those of the choicest vintages of Burgundy. Pasteur writes that "at its outset the wine assumes a peculiar smell, its colour is less vivid, and its taste becomes insipid. Soon the wine becomes bitter, and there is a slight taste of fermentation, due to the presence of carbonic acid gas. Finally, the disease becomes more aggravated, the colouring matter is completely changed, and the wine is no longer drinkable."

The microbe which is the essential cause of this disease is seen under the micrpscope in the form of articulated filaments, curled back or bent, and it may, or may not, be invested with the colouring matter of the wine. It is reproduced by fission, not by budding. It is probably a bacillus (Fig. 56).

This ferment must not be confounded with that of wine affected by *pousse*, of which the filaments are much more slender, the articulations are hardly apparent, and they are not incrusted with colouring matter. *Pousse* is readily developed in wines of inferior quality, while the finer sorts are more often attacked by bitterness.

The bitterness may be to some extent neutralized by the addition of new and sweet wines, but the application of lime (from 25 to 50 centigrammes the

Fig. 56.—Bitter disease of wine. Deposit under the microscope: 1, 2, filaments of the microbe (*Bacillus*) which produces the disease, mixed with crystals of tartar and colouring matter (Bordeaux wine); 3, young microbes in an active state; 4, dead microbes, incrusted with colouring matter.

litre) is more recommended. This treatment must, however, make the wine sour.

The deposits formed in deteriorating or old wines are not effected by the microbes which we have just enumerated, but are due, according to Pasteur, to the combination of oxygen with the wine under the action of time. This constitutes the aging of wine.

Viscous Fermentation of Saccharine Liquids.—What is termed viscous fermentation takes place in the juice of beetroots, carrots, and onions, and in liquids containing sugar and nitrogenous substances. It is probably produced by the same ferment which causes the ropiness of wine (Fig. 55), and the liquid assumes a viscous or oily appearance.

Pasteur states that this microbe acts on the glucose and transforms it into gum or dextrine, into mannite and carbonic acid. The lactic and butyric fermentations, which are often simultaneously produced in saccharine liquids, are due to distinct microbes.

V. The Microbe of Lactic Fermentation.

The sugar contained in milk, as well as grape sugar, can be transformed into lactic acid. This transformation is always caused by the presence of a ferment with which Pasteur has made us acquainted. It had been previously supposed that milk turned sour *spontaneously* when it was allowed to stand for some days. In this case, as we know, the milk curdles, and the clear liquid which separates from the curd is called whey. In 1780, Scheele, the celebrated Swedish chemist, extracted lactic acid from whey. The same acid is also found in sour-crout; in the sour water of starch; in baker's yeast; in water in which peas, beans, or rice have been boiled, and then suffered to ferment; and, finally, in the juice of beetroot which has passed through viscous and alcoholic

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fermentation, after which it turns sour and produces lactic acid and mannite.

Lactic fermentation requires the presence of proteid matters in process of decomposition, and it can only be carried on when the degree of acidity in the liquid does not exceed definite limits. For this purpose a certain amount of chalk is added, to neutralize the acid formed at the expense of the sugar.

It is somewhat difficult to observe the microbe of this fermentation without previous instruction. It appears in the form of grey patches, which are readily confounded with casein, and with the disintegrated gluten, or the chalk of the liquid under examination.

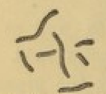


Fig. 57.—Lactic ferment in a chaplet (Schutzenberger).

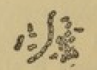


Fig. 58.—Lactic ferment (Pasteur).

Under the microscope the patch is seen to consist of minute globules, or of filaments with very short articulations, isolated or in flakes. These are the characters of the genus *Bacterium* (Figs. 57, 58). The globules are much more minute than those of the yeast of beer, and are strongly agitated when in isolation by a motion incorrectly termed Brownian movement, and which does not in reality differ from the movements which may be observed in most of the spores of the lower orders of plants, and in a great number of bacteria.

This ferment is often found in wine, together with those of yeast and alcohol, and produces in it an incipient lactic fermentation. The predominance of one of these fermentations depends on the composition of the medium, which may be more or less adapted to them. A slightly alkaline medium is most suitable for the lactic microbe, while in a perfectly neutral medium only alcoholic fermentation will occur.

We have already said that mare's milk can be transformed into an alcoholic liquid called koumiss.

VI. The Ammoniacal Fermentation of Urine.

Shortly after its discharge, urine which is left to itself assumes an ammoniacal odour. This is due to the transformation of the urea (the nitrogenous principle of urine) into ammonia and carbonic acid, under the influence of a microbe which appears in the form of free globules, of articulated filaments (*Torula*), or of chaplets, resembling those of the lactic ferment. This microbe is found in the white deposit which collects at the bottom of vessels, and has been termed *Micrococcus ureæ* (Fig. 59).

This ferment is conveyed through the air, like other microbes of fermentation. It does not exist in the bladder as long as the urine remains acid. Yet, in the rare cases in which urine has been found to be alkaline, immediately after its issue from the bladder, it may be ascertained that the ferment was introduced by some accidental cause, such as a surgical examination, and that the sound served to convey the microbe. It is, in any case, sufficiently common at the exterior orifice of the urethra, and at the depth of two or three centimetres.

Von Tieghem has shown by precise experiments

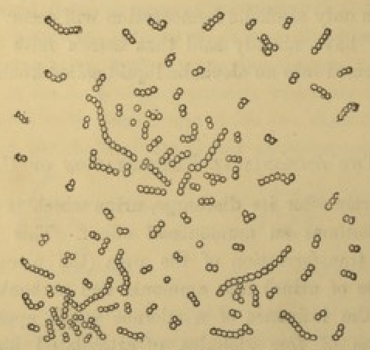


Fig. 59.—*Micrococcus ureæ* (Von Tieghem). Microbe of ammoniacal fermentation. It may be observed that the bacterium is in the figure 8, or in chaplets. (Much magnified.)

that the presence of this microbe is the true cause of the ammoniacal fermentation of urine. With certain precautions, the urine withdrawn from a healthy bladder may be preserved for an indefinite time.

These experiments have been recently resumed by Sternberg, an American physician, who has clearly demonstrated that only the microbes of the air, or those of the orifice of the urethra, can produce this fermentation. Since the latter are always carried off by the first discharge of urine, only the second portions of the emitted liquid should be collected in a perfectly clear vessel, which has been sterilized, or, carefully freed from all atmospheric germs. The vessel should then be put under a glass shade to protect it from these germs, and if all proper precautions are taken, the urine will remain clear and acid for an indefinite time without undergoing ammoniacal fermentation. If afterwards a little plug of amianthus, which has been previously sterilized by heat, should be introduced by a small pair of pincers into the urethra to a depth of two centimetres, and then dropped into this untransformed urine, it will soon be transformed, and undergo ammoniacal fermentation. But if the plug of amianthus has been steeped in an antiseptic solution (diluted carbolic acid) before being introduced into the urethra, it will not produce this fermentation.

VII. Butyric Fermentation of Butter, Cheese, and Milk.

Butyric fermentation follows lactic fermentation in milk, butter, and cheese, and it is butyric acid which gives to butter its rancid taste. This fermentation also occurs in saccharine substances, and generally in all proteid substances.

Pasteur has ascertained that this fermentation results from the development of a microbe which takes the form of minute cylindrical rods, rounded at their extremities, usually straight, and either isolated or united in chains of two or more articulations. These rods are about two micro-millimetres in width, and from two to twenty micro-millimetres in length. They advance with a gliding motion, are often curved, and present slight undulations. They are reproduced by fission. These characters are those of the genus bacillus.

Coagulation of Milk: Cheese.—The coagulation of milk is artificially produced by rennet, the liquid secreted in a calf's stomach. Human gastric juice produces the same effect, and the milk introduced as an aliment into the stomach is never digested until it has been curdled, both in children and adults. The artichoke flower, and other plants of the genus *Carduus*, will also curdle milk at a temperature between 30° and 50°. It is probable that this action is due to the presence of an organized ferment (animal or vegetable cells), which here supplies the place of the microbe of lactic fermentation.

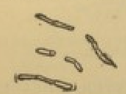


Fig. 60.—*Bacillus amylobacter* (or *butyricus*), butyric ferment, agent in the fabrication of cheese.

It is with rennet, or with the still more active liquid produced by the maceration of the testicle of an unweaned calf, that those cheeses are made which consist only of curd, boiled or unboiled, fresh or fermented, and obtained from the milk of cows, sheep, or goats, skimmed or unskimmed, according to the kind of cheese desired.

Sweet-milk cheese do not differ in their composition from those of curdled milk. They consist of casein, albuminoid matter which encloses particles of butter: the liquid residue is the serum or whey, which contains lactic acid and mineral salts.

Cheese, strictly so called, such as Gruyère and Roquefort, only differ from the foregoing because they have been exposed for a shorter or longer time to the action of the air, and of the microbes suspended in it. Cheese is first oxidized under the influence of the oxygen of the air; butyric and even alcoholic fermentation soon follows lactic fermentation, together with the disengagement of hydrogen and of putrid products, when the action of the ferments which effect these transformations has gone on too long.

In order to obtain the different kinds of cheese which come into the market, they are exposed to the weather, generally in holes which have been excavated in the rock for this purpose, on a bed of straw, or sometimes partially covered with it, until the cheese is ripe and has attained the desired quality.

Butyric and ammoniacal fermentations lead us directly to the study of putrefaction; that is, the fermentation of dead organic matter.

VIII. Putrefaction, or the Fermentation of Dead Organic Matter; a Game Flavour.

The flesh of animals used for food is said to be *high* in the first stage of alteration which occurs when it is left to itself. Pasteur does not believe that this effect is produced by the intervention of the ferments of the air, although this is the case with the putrefaction which follows. He thinks that it merely results from the action of what are called *soluble* or *natural* ferments in the serum of the meat, and that there is a chemical, reciprocal reaction of the liquids and solids which are withdrawn from the normal action of vital nutrition. This explanation is adapted to satisfy those epicures who have a taste for high game and not for microbes. Yet it is certain that this condition passes into true putrefaction without any abrupt transition, and we know that immediately after death the microbes, which penetrate everywhere, take possession of the animal tissues and begin their work of destruction. When flesh is high, it is therefore probable that it is in the first stage of putrefaction.

Gautier has made some experiments on the subject, and holds that this condition is certainly due to the action of microbes, and consequently to germs in the air. In fact, meat which is placed in a soldered and air-tight case after it has been deprived of germs by a suitable process, is devoid of any *high* odour at the end of six months, and is as fit for food as freshly killed meat.

However this may be, meat which is high is usually not injurious, while putrefied meat produces diarrhœa or still more serious illness. Davaine has shown that the septic properties of decomposed blood are not removed by subjecting it to a temperature of 100°, which destroys the microbes, but not their germs or spores; for the destruction of the latter a still higher temperature is necessary.

For a long while it was believed that the putrefaction of dead bodies, and of albuminoid substances, either animal or vegetable, which have been exposed to a moist air at a temperature of from 15° to 30°, was merely due to the instability of the organic compounds; these, when left to themselves, tend, under the influence of oxygen, to produce more stable compounds by disintegration and successive oxidations. Pasteur has, however, shown that in this case also there is a true fermentation; that is, a decomposition produced by the vital action of certain microbes.

In general, when organic animal substances are exposed to the air, they are in the first instance rapidly covered with moulds; they lose their coherence, and after the lapse of a few days give off fetid effluvia. Carbonic acid, nitrogen, hydrogen, carburetted, sulphuretted, and phosphoretted hydrogens, are freely disengaged, and at the same time they combine with the oxygen of the air. The microbes, which appear simultaneously with the moulds, penetrate deeply into the tissues, disintegrate them by feeding at their expense, and the putrid condition increases; then the decomposition changes its nature and becomes less intense. The putrefied matter is finally desiccated, and leaves a brown mass—a complex mixture of substances combined with water (hydrocarbons), and of fatty and mineral substances which gradually disappear by slow oxidation (Gautier).

Pasteur has ascertained, from the microscopic

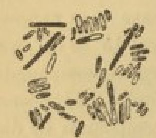


Fig. 61.—Bacilli of putrefaction (Rosenbach: much magnified.)

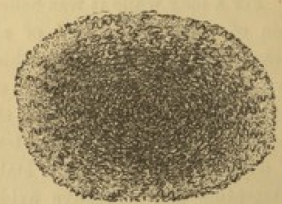


Fig. 62.—*Zoogloea* of *Spirillum tenue*.

study of the phenomena which occur in an infusion of animal matter in process of decomposition, that microbes appear in it in the form of globules or short rods (*Micrococcus*, *Bacterium termo*, *Bacillus*, etc.), which are either free or collected in a semi-mucilaginous mass, to which the special name *zoogloea* was at first given (Fig. 62). These microbes rapidly deprive the liquid of all its oxygen. At the same time a thin layer of *mucedineæ* and of bacteria is found on the surface, which also absorb this gas and do not allow it to penetrate into the lower part of the liquid.

This liquid now becomes the seat of two very distinct actions. In its interior, vibriones succeed to the free globules and *zoogloea*, of which they appear to be only a higher stage of transformation. These microbes multiply and change the albuminoid matter into more simple substances; insoluble cellulose, fatty bodies, and gaseous putrid matters. Meanwhile, the microbes on the surface actively consume the products thus developed, transforming them into carbonic acid, nitrogen, and the oxides of nitrogen, etc. This explains why, when there is an insufficiency of oxygen, putrefaction may indeed begin; but it languishes, and is finally arrested.

The cause of the fetid odours which escape from putrefying bodies and liquids is not well understood. It may be ascribed to the disengaged gases (carburetted, phosphoretted and sulphuretted hydrogen, and ammoniacal compounds), and to the circulation of decomposing organic particles. We also find formic, acetic, lactic, butyric, valerianic, and caproïc acids, generally combined with ammonia, and the fatty acids which are one result of the successive disintegrations of albuminoid matters.

When these gases are disengaged, a substance remains which may be compared with *humus*, or vegetable earth. It is rich in fats, in earthy and ammoniacal salts, and consequently constitutes a strong manure, very fit to serve as the nutriment of plants.

This is at once the beginning and the termination of the endless chain which sustains the equilibrium of nature, in which there is no creation, no destruction. Plants draw their nutriment from the soil and the air in the form of mineral solutions, and are devoured by animals or by other parasites; animals are in their turn devoured by microscopic plants or microbes, and return by means of putrefaction to the condition of mineral salts, which are distributed in the soil, and serve anew for the nutrition of plants.

We must at the same time be struck by the resemblance which exists between these phenomena of putrid fermentation, and those which occur in the fermentations which accompany the nutrition of animals and plants. Germination and the different digestions which occur in the mouth, the stomach, the intestines, etc., are only fermentations, so that Mitscherlich has paraphrased the Scripture saying, "Dust thou art, and unto dust thou shalt return," by declaring that "Life is only a corruption."

It should, however, be remembered that fermentations are essentially phenomena of disintegration, which always reduce complex, organic substances to those which are simpler. Plants provided with chlorophyl, on the other hand, alone possess the property of forming higher organic compounds, by the aid of purely inorganic substances. Animals and plants devoid of chlorophyl get their nutriment by unmaking the complex substances elaborated by the green parts of plants, and these act in the same way for their own profit in those organs which have no chlorophyl; as, for instance, in the seed and embryo.

IX.—Aërobies and Anaërobies.

We have seen that microbes, at different epochs of their existence, and in accordance with the nature of their environment, can assume very diverse forms. Thus the organism, which at first appears in the form of globules (*micrococcus*), either isolated or united in more or less numerous colonies by a kind of mucilaginous envelope (*Zoogloea*), when it again becomes free, may be elongated in the shape of the figure 8, which is formed of two cells about to separate; or a large number may be included in the form of a straight, articulated rod (*Bacterium*), or in a rod which is curved, waved, or even spiral (*Vibrio, Spirillum, Spirochœte*), always more or less mobile; or, again, the cells may form long, stationary filaments (*Bacillus*), etc.

So also the habitat and mode of life divide the microbes into very distinct classes. Some can only subsist when they breathe the natural oxygen they withdraw from the atmosphere; they can only exist on the surface of liquids, or of the organic substances on which they feed. These are termed *aërobies*, or consumers of air. Others, again, can live beneath the surface of liquids and in living organisms, or of those in process of decomposition, and must necessarily derive the oxygen necessary for their respiration from the oxygenated substances in which they are found. These are termed *anaërobies*.

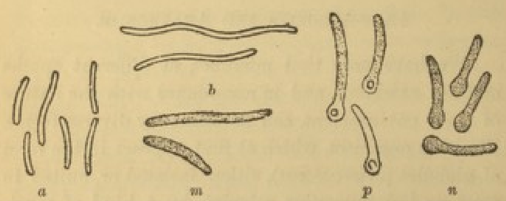


Fig. 63.—*Vibrio rugula* in different stages of development (anaërobie), much enlarged.

This distinction and the theory on which it relies have been introduced into science by Pasteur, and they appear to be founded on observed facts. Thus *Bacterium termo*, which lives on the surface of putrefying liquids, is an aërobie; while *Vibrio rugula* (Fig. 63), which lives below the surface of the liquid, below the layer formed by the *Bacterium termo*, is an anaërobie, and derives its oxygen from the water or solid matters which are found in it in suspension or solution, and even from other microbes. So, again, the yeast of superior beer is an aërobie, and the yeast of inferior beer is an anaërobie, etc. Paul Bert regards the corpuscles of the blood, and the cells of which all our tissues consist, as true anaërobic microbes; so likewise are the microbes which, when introduced into the blood, are the cause of certain diseases. The important consequences of this fact, which it is necessary to note, will appear presently.

X.—The Microbes of Sulphurous Waters.

The formation of the sulphurous springs which are so numerous in the Pyrenees and in other parts of France, appears to be due to the presence of small algæ of the family *Oscillatoria*, and of the genera *Oscillaria* and *Beggiatoa* (Fig. 64). These microbes are of the same structure as those of which we have spoken above, but they contain chlorophyl, and also a blue colouring matter. They are placed in the group *Cyanophyceæ*, which, as Zopf believes, contains species that are sometimes green, and sometimes colourless, like *Bacillus* and *Leptothrix*, which they resemble in their mode of reproduction.

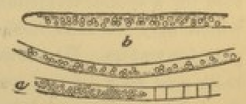


Fig. 64.—*Beggiatoa alba*, microbe of sulphurous springs.

According to Louis Ollivier, these algæ reduce the sulphates of waters charged with sulphate of lime, transforming them into sulphur. They even accumulate sulphur in their cells. When sulphur is thus abundantly supplied to them, the microbes are very mobile; as soon as the quantity of sulphur diminishes they become less mobile, and reconsume the sulphur they have stored up; finally, they become quite motionless—a phenomenon concomitant with the formation of spores. Within each cell of the filamentous alga there is a minute sphere, brilliant and refracting, of which the development is in inverse ratio to the quantity of sulphur in the surrounding liquid. These spores become free in the form of chaplets, after the destruction of the cell-wall, and these chaplets are precisely like those of *Bacillus subtilis*.

Planchud was the first to whom it occurred to look for a special ferment in the *glairine* or *barégine* which may be seen floating on the surface of sulphurous waters. He showed that one gramme of carbolic acid to a litre of water arrests the reduction of the sulphates into sulphur, and that this reduction is resumed as soon as the carbolic acid has evaporated. Six grammes to the litre completely destroy the *Sulphuraria*, as these algæ are termed by Planchud.

This observer also performed experiments which led him to believe that the same algæ will reduce gypsum to native sulphur, and that the vast deposits of sulphur found in certain regions are due to the action of this microscopic plant. It is now well known that a chemical action of the same nature, the production of saltpetre, is the work of similar microbes.

XI. The Microbes which produce Saltpetre.

It is known that nitre or saltpetre, *i.e.* potassium nitrate, is produced in damp places where decomposing animal matter is found in contact with carbonate of potassium. It is found, combined with other salts of lime, soda and magnesia, in stables, sheep-folds, cellars, in the neighbourhood of urinals, and in the earth of some localities (Peru and Chili). Its industrial importance in the manufacture of gun-powder, etc., has led to its collection. Formerly it was extracted from the plaster of old houses, or from artificial nitre works which combined conditions favourable to its production. Nitrates are produced by the gradual oxidation of the ammonia furnished by animal excretions. For a long while it was supposed that this oxidation was simply due to the influence of porous bodies, such as earth and stone walls. Nitric acid was produced, then nitrates of lime, potassium, etc.

The researches of Boussingault, Schlœsing, and others, have now taught us that this phenomenon of organic chemistry is due, like many others, to the vital activity of one or more species of microbe, whose invariable presence in the natural or artificial nitre-works has been ascertained. These microbes are aërobies, *i.e.* they only live and work when in contact with the oxygen of the air, from which they derive materials for effecting oxidation. This is another instance of the part played by microbes in artificial fermentation.

Gayon and Dupetit believe that, in addition to the microbes which produce nitre, there are others which decompose the nitrates produced by the former. When nitrate of potassium is placed in culture-liquids, drain-water, chicken-broth, etc., it disappears rapidly under the action of these microbes. Under favourable conditions of temperature and environment, culture microbes daily reduce one gramme of nitre to the litre. This decomposition causes the disengagement of nitrogen, the formation of ammonia and carbonic acid, which latter remain in solution in the form of bicarbonate. Gayon and Dupetit believe that this fact explains certain chemical phenomena which occur in the soil, under the influence of manure and water.

Thus fresh discoveries show more clearly every day the importance of the part played by microbes in nature. Agriculture, manufactures, geology, and chemistry must take them into account, since they are the active agents of a number of phenomena which have hitherto been obscure in physics, chemistry, and physiology.

XII. THE MICROBES WHICH DESTROY BUILDING MATERIALS.

The observations of Parize, director of the agronomic station, Morlaix, lead to the belief that microbes, which destroy dead bodies and effect such various transformations in nature, not only attack the beams of our houses, as we have already seen, but building materials of an inorganic nature, including stones.

On one occasion, when Parize was examining some *mucedineæ* which had vegetated on a brick partition, in a closed and somewhat damp recess, he noticed blisters on the coat of plaster. He broke one of these blisters, and a fine red dust, consisting of pulverized brick, issued from it. When placed in the microscope, under a magnifying power of about 300 diameters, he saw, amid schistoid fragments, diatomaceæ and silicious algæ pertaining to the original clay of the bricks, an immense number of living microbes: micrococcus, bacteria, amœbæ, and ciliated spores of algae, moving rapidly in the drop of water used to moisten the dust. Some of these were in process of budding. These organisms existed under a coat of five to six mm. of plaster, and even of 30 mm. at the bottom of a hole pierced by the brace; but in this case they were less numerous, in the proportion of two to three. The germs and spores which exist both in air and water may, therefore, be indefinitely preserved in a protective medium, such as a brick wall covered with plaster. They are nourished at the expense of the ammoniacal salts which are found in the air in a gaseous state, and which are fixed by atmospheric moisture, and it is probable that they derive little nutriment from the solid materials in the midst of which they live, although by their increase disintegration may ensue. Hence, especially from the hygienic point of view, it is so important to disinfect the walls of hospitals, barracks, stables, etc., by scraping and whitewashing them.

Parize also believes that microbes may perform a geological part in nature by disintegrating the schistoid rocks which enter into the constitution of arable soil. But we are now speaking of microbes of recent origin, since the temperature to which clay is subjected in order to make red bricks would certainly destroy all the microbes and their germs. This is not the case with the microbes of chalk, which, according to Béchamp, are of very ancient origin.

XIII. The Microbes of Chalk and Coal.

Béchamp's researches tend to show that microbes, which he calls *microzyma*, or small ferments, have an almost indefinite term of life. We know that chalk consists almost entirely of the remains of the calcareous shell of *Rhizopoda*, protozoaria or microscopic animals which lived in incalculable numbers in the seas of the secondary period, and which still live at the bottom of oceans. Béchamp holds that the organic substance of these rhizopoda, or of the microbes which live in their midst, has retained its vitality in the mass of chalk, since a freshly cut piece, taken from the quarry with all possible precautions to exclude air-germs, is able to furnish microbes which multiply rapidly in a favourable medium, and produce various fermentations. We have already seen that bacteria germs resist desiccation, heat, and all kinds of destructive influences, and remain for a long while, even for several years, in the condition of dormant spores; but the existence of spores of the same kind in chalk of the secondary period indicates a still more surprising vitality. It is not, however, inexplicable if we suppose that these microbes pass through successive periods of activity and repose, and if we compare these facts with those presented by the microbes of saltpetre, of mineral waters, and of the anaërobic microbes, which are able to live when deprived of the oxygen of the air.

Béchamp was the first to observe the presence of granulations in coal, which appear under the microscope to be microbes. These microbes must be far more ancient than those of chalk, but they have lost all vitality; it has been found impossible to develop them in infusions, and to obtain fermentations from them. But this cannot always have been the case, and it has been supposed that the phenomenon of coal formations, still so obscure and so variously explained, was, at any rate, partially due to the physiological labour of these microbes, and consequently belongs to the class of fermentations.

XIV. Chromogenic Microbes.

In addition to the colourless microbes, such as are most of those we have hitherto considered, there are others remarkable for their vivid and varied colours, which betray their existence to the least practised eyes. Many of these microbes attack our alimentary substances, and should therefore be known to the manufacturer and hygienist, since their action on the human system is often injurious.

Many phenomena which have struck the imagination of ignorant and credulous people are merely due to the presence of these coloured microbes. In 1819, a peasant of Liguara, near Padua, was terrified by the sight of blood-stains scattered over some polenta, which had been made and shut up in a cupboard on the previous evening. Next day similar patches appeared on the bread, meat, and other articles of food in the same cupboard. It was naturally regarded as a miracle and warning from heaven, until the case had been submitted to a Paduan naturalist, who easily ascertained the presence of a microscopic plant, which Ehremberg likewise found at Berlin in analogous circumstances, and which he named *Monas prodigiosa*. At that time all microbes were confounded in the *Monad* genus; we now term it *Micrococcus prodigiosus*. It has been observed not only on bread, but on the Host, on milk, paste, and on all alimentary or farinaceous substances exposed to damp heat.

This microbe has been recently studied by Rabenhorst, who declares that it is polymorphic, and has received a number of different names: *Palmella mirifica, Zoogalactina imetropha, Bacterium prodigiosum*, which are only varieties of *Micrococcus prodigiosus*, modified by the medium in which it is nourished. This observer noticed its appearance on cooked meat kept in a cellar. The spherical cells, examined under the microscope, were shown to be filled with a reddish oil, which gave them a peach-blossom tint, and when transferred to raw meat they assumed a splendid fuchsia colour, resembling spots of blood. This plant is only developed in the dark, and the nitrogen necessary for its nutrition must be derived from the air, especially when it is developed on bread, the Host, etc., in which nitrogen is deficient.

When it is said to rain blood, this phenomenon is likewise due to the presence of a minute plant, probably similar to that which often gives a red tint to ponds and reservoirs in autumn. This microscopic alga appears to be the one discovered by Ehremberg in

1836, in a stream near Jena, and which he named *Ophidomonas jenensis*, or *sanguinea* (Fig. 65). It is, on account of its form, now placed in the genus *Spirillum*. Like many other plants, it readily passes from green to red. No one is surprised by the green scum which covers reservoirs in summer, since it is so common; but when this colour changes, often in a single night, and passes from green to red, the unaccustomed tint excites wonder, although it is caused by

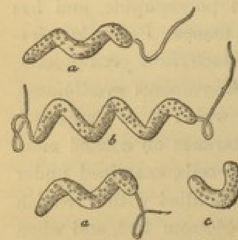


Fig. 65.—*Ophidomonas sanguinea* of stagnant water (slightly magnified).


Fig. 66.—*Protococcus nivalis* of red snow (magnified).

the same plant which was green the day before. If there is a thunderstorm or waterspout which draws up the red water from the ponds and reservoirs, and discharges it in the form of rain on the surrounding country, we hear of the phenomenon that it rains blood, and it would be easy to find in the drops of rain the reddish microbe which imparts this colour to them.

In northern regions the snow is often tinged with the colour of blood by an analogous *Micrococcus*, which presents the same transition from green to red (Fig. 66). Green-tinted snow may be found adjacent to the red snow, and under the microscope it displays minute green globules, identical, except in colour, with those of the red-tinted snow.

The variety of colour in these microbes is extreme. *Micrococcus aurantiacus* gives an orange colour to

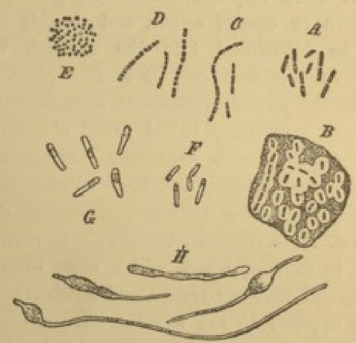


Fig. 67.—*Bacterium cyanogenum*, microbe of blue milk (Neelsen). It is probable that several different forms are here confused under this name. *B*, zoogloea.

bread and eggs; *M. chlorinus* is grass-green; *M. cyanus* is of a beautiful azure blue; *M. violaceus* is violet or lilac, and *M. fulvus* is rust-coloured. These have all been observed on food. *M. candidus* forms little white patches upon cheese.

The genus Bacterium also furnishes its contingent of coloured species; such are *B. xanthinum* and

B. cyanogenum, which give respectively a yellow or blue colour to milk (Fig. 67). Peasants say that an evil eye has been cast upon the milk, but it is easy to prove that the development of these microbes is due to imperfect cleansing of the tin milk-vessels, since the discolouration ceases when greater care is taken to wash and scald the vessels.

Bread often displays microscopic growths of a dark green or orange colour, and in this state it cannot be introduced into the stomach without danger. In the first case it is *Bacterium œruginosum*, in the second *Micrococcus aurantiacus*. The badly made and badly baked bread of the French peasants, which is often kept for a fortnight or more, exposed to the moisture and heat which favour the development of these microbes, sometimes displays the first of these changes; the second is particularly common in soldiers' bread, which must likewise be baked several days in advance, and which is conveyed in carts exposed to the weather. Mégnin recently observed a cryptogamic growth of this kind on the bread distributed to the garrison of Vincennes.

The spores of these microbes are found in flour, and resist a temperature of 120°, while they are destroyed by that of 140°. Thus they are no longer found in the crust, of which the temperature rises to 200°; but may easily subsist in the much lower temperature of the crumb. Hence the necessity of only using flour perfectly free from germs.

The pus of wounds is often coloured blue by an aërobic micrococcus, of which the protoplasm is colourless, but which makes a colouring matter called *pyocyanine*, and this gives a blue tint to the lint and bandages used for dressing the wound.

XV. The Microbe of Baldness.

In addition to the numerous parasitic fungi of skin on which the hair grows thickly, which we have already noticed, the human hair is attacked by a true microbe, which is, according to the researches of Gruby, Malassez and Thin, the cause of *Alopecia areata*, one form of baldness. The parasite has the appearance of a micrococcus, and penetrates the interior of the hair, which is, as we know, hollow. The hair must be made transparent by potash, in order to see the microbe. It probably penetrates between the bulb and the hair-follicle as far as the root, is introduced into the hair, and multiplies and gradually rises higher in it, until the substance is disorganized. This microbe has been called *Bacterium decalvans.*

CHAPTER IV.

MICROBES OF THE DISEASES OF OUR DOMESTIC ANIMALS.

I. ANTHRAX, OR SPLENIC FEVER.

THE first of the virulent and contagious diseases in which the presence of a microbe was positively ascertained was anthrax, or splenic fever, which attacks most of our horned animals, and especially cattle and sheep.

As early as 1850, Davaine had observed the presence of minute rods in the blood of animals which died of splenic fever; but it was only in 1863, after Pasteur's first researches into the part played by microbes in fermentations, that Davaine suspected these rods of being the actual cause of the disease. He inoculated healthy animals with the tainted blood, and thus ascertained that even a very minute dose would produce a fatal attack of the disease, and the rods, to which he gave the name of *Bacteridia*, could always be discovered in enormous numbers in the blood.

The microbe so named by Davaine must from its characteristics be assigned to the genus Bacillus, and is now termed *Bacillus anthracis*. This disease, which affects men as well as animals, is characterized by general depression, by redness and congestion of the eyes, by short and irregular respiration, and by the formation of abscesses, which feature, in the case of the human subject, has procured for it the name of malignant pustule. The disease is quickly terminated

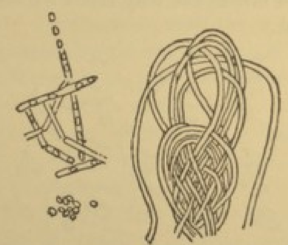


Fig. 68.—*Bacillus anthracis* of splenic fever in different stages of development: bacilli, spores, and curled filaments (much enlarged).

by death, and an autopsy shows that the blood is black, that intestinal hæmorrhage has occurred, and that the spleen is abnormally large, heavy, and gorged with blood; hence the name of splenic fever. The disease is generally inoculated by the bite of flies which have settled upon carcases and absorbed the bacteria, or by blood-poisoning through some accidental scratch, and this is especially the case with knackers and butchers who break and handle the bones of animals which have died of anthrax.

The period of incubation is very short. An ox which has been at work may return to the stall apparently healthy. He eats as usual; then lies down on his side and breathes heavily, while the eyes are still clear. Suddenly his head drops, his body grows cold; at the end of an hour the eye becomes glazed; the animal struggles to get up, and falls dead. In this case, the illness has only lasted for an hour and a half (Empis).

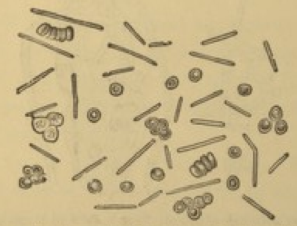


Fig. 69.—*Bacillus anthracis*, produced in guinea-pig by inoculation: corpuscles of blood and bacilli.

In order to prove that the disease is really caused by *Bacillus anthracis*, Pasteur inserted a very small drop of blood, taken from an animal which had recently died of anthrax, in a glass flask which contained an infusion of yeast, neutralized by potassium and previously sterilized. In twenty-four hours the liquid, which had been clear, was seen to be full of very light flakes, produced by masses of bacilli, readily discernible under the microscope. A drop from the first flask produced the same effect in a second, and from that to a third, and so on. By this means the organism was completely freed from all which was foreign to it in the original blood, since it is calculated that after from eight to ten of such processes, the drop of blood was diluted in a volume of liquid greater than the volume of the earth. Yet the tenth, twentieth, and even the fiftieth infusion would, when a drop was inserted under the skin of a sheep, procure its death by splenic fever, with the same symptoms as those produced by the original drop of blood. The bacillus is, therefore, the sole cause of the disease.

These cultures have often since been repeated by numerous observers, so that the microbe has been studied in all its forms, and the extent of its polymorphism has been ascertained. At the end of two days the bacterium, which, while still in the blood, is of a short, abrupt form, displays excessively long filaments, which are sometimes rolled up like a coil of string. In about a week many of the filaments contain refracting, somewhat elongated nuclei. These nuclei presently form chaplets, in consequence of the rupture of the cell-wall of the rod which gave birth to them; others, again, float in the liquid in the form of isolated globules. These nuclei are the spores or germs of the microbes, which germinate when placed in the infusion, become elongated, and reproduce fresh bacilli.

These spores are much more tenacious of life than the microbes themselves. The latter perish in a temperature of 60°, by desiccation, in a vacuum, in carbonic acid, alcohol, and compressed oxygen. The spores on the other hand, resist desiccation, so that they can float in the air in the form of dust. They also resist a temperature of from 90° to 95°, and the effects of a vacuum, of carbonic acid, of alcohol, and compressed oxygen.

In 1873, Pasteur, aided by Chamberland and Roux, carried on some experiments on a farm near Chartres, in order to discover why this disease is so common in some districts, in which its spread cannot be ascribed to the bite of flies. Grass, on which the germs of bacteridia had been placed, was given to the sheep. A certain number of them died of splenic fever. The glands and tissues of the back of the throat were very much swelled, as if the inoculation had occurred in the upper part of the alimentary canal, and by means of slight wounds on the surface of the mucous membrane of the mouth. In order to verify the fact, the grass given to the sheep was mixed with thistles and bearded ears of wheat and barley, or other prickly matter, and in consequence the mortality was sensibly increased.

In cases of spontaneous disease it was surmised that the germs which were artificially introduced into food in the course of these experiments, are found upon the grass, especially in the neighbourhood of places in which infected animals had been buried. It was, in fact, ascertained that these germs existed above and around the infected carcases, and that they were absent at a certain distance from their burial-place. It is true that putrid fermentation destroys most of the bacteria, but before this occurs a certain number of microbes are dispersed by the gas disengaged from the carcase; these dry up and produce germs, which retain their vitality in the soil for a long while.

The mechanism by means of which these germs are brought to the surface of the soil and on to the grass on which the sheep feed is at once simple and remarkable. Earth-worms prefer soils which are rich in humus or decomposing organic substance, and seek their food round the carcase. They swallow the earth containing the germs of which we have spoken, which they deposit on the surface of the soil, after it has traversed their intestinal canals, in the little heaps with which we are all acquainted. The germs do not lose their virulence in their passage through the worms' intestines, and if the sheep swallow them together with the grass on which they browse, they may contract the disease. The turning-up of the soil by the spade or plough may produce the same effect.

A certain warmth is necessary for the formation of germs; none are produced when it falls below 12°, and the carcases buried in winter are therefore less dangerous than those buried in the spring and summer. It is, in fact, in hot weather that the disease is most prevalent. Animals may, however, contract it even in their stalls from eating dry fodder on which germs of these bacteria remain.

Pasteur and his pupils performed an experiment in the Jura in 1879, which clearly shows that the presence of germs above the trenches in which carcases have been buried is the principal cause of inoculation. Twenty oxen or cows had perished, and several of them were buried in trenches in a meadow where the presence of these germs was ascertained. Three of the graves were surrounded by a fence, within which four sheep were placed. Other sheep were folded within a few yards of the former, but in places where no infected animals had been buried. At the end of three days, three of the sheep folded above the graves had died of splenic fever, while those excluded from them continued to be healthy. This result speaks for itself.

Malignant pustule, which is simply splenic fever, affects shepherds, butchers, and tanners, who handle the flesh and hide of tainted animals. Inoculation with the bacillus almost always occurs in consequence of a wound or scratch on the hands or face. In Germany, fatal cases of anthrax have been observed, in which the disease has been introduced through the mouth or lungs, as in the case of the sheep observed by Pasteur. The human subject appears, however, to be less apt to contract the disease than herbivora, since the flesh of animals affected by splenic fever, and only killed when the microbe is fully developed in the blood, is often eaten in farmhouses. In this case the custom prevalent among French peasants of eating over-cooked meat constitutes the chief safeguard, since the bacteria and their germs are thus destroyed.

II. Vaccination for Anthrax.

The rapidity with which anthrax is propagated by inoculation generally renders all kinds of treatment useless; if, however, the wound through which the microbe is introduced can be discovered, it should be cauterized at once. This method is often successful in man. The pustule is cauterized with red-hot iron, or with bichloride of mercury and thymic acid, two powerful antiseptics, certain to destroy the bacteridium. It is expedient, as an hygienic measure, to burn the tainted carcases, and if this is not done, they should be buried at a much greater depth than is usually the case.

But the preservative means on which chief reliance is now placed is vaccination with the virus of anthrax. Pasteur has ascertained that when animals are inoculated with a liquid containing bacteridia of which the virulence has been attenuated by culture carried as far as the tenth generation, or even further, their lives are preserved. They take the disease, but generally in a very mild form, and it is an important result of this treatment that they are henceforward safe from a fresh attack of the disease; in a word, they are *vaccinated* against anthrax.

In the cultures prepared with the view of attenuating the microbe, it is the action of the oxygen of the air which renders the bacteridium less virulent. It should be subjected to a temperature of from 42° to 43° in the case of *Bacillus anthracis*, to enable it to multiply, and at the same time to check the production of spores which might make the liquid too powerful. At the end of the week, the culture, which at first killed the whole of ten sheep, killed only four or five out of ten. In ten or twelve days it ceased to kill any; the disease was perfectly mild, as in the case of the human vaccinia, of which we shall speak presently. After the bacteridia have been attenuated, they can be cultivated in the lower temperature of from 30° to 35°, and only produce spores of the same attenuated strength as the filaments which form them (Chamberland).

The vaccine thus obtained in Pasteur's laboratory is now distributed throughout the world, and has already saved numerous flocks from almost certain destruction. Although this process has only been known for a few years, its results are such that the gain to agriculture already amounts to many thousands of pounds.

Toussaint makes use of a slightly different mode of preparing a vaccine virus, which is, however, analogous to that of Pasteur. He subjects the lymph of the blood of a diseased animal to a temperature of 50°, and thus transforms it into vaccine. Toussaint considers the high temperature to be the principal agent of attenuation, and ascribes little or no importance to the action of the oxygen in the air.

Chamberland and Roux have recently made researches with the object of obtaining a similar vaccine by attenuating the primitive virus by means of antiseptic substances. They have ascertained that a solution of carbolic acid of one part in six hundred destroys the microbes of anthrax, while they can live and flourish in a solution of one part in nine hundred, but without producing spores, and their virulence is attenuated. When a nourishing broth is added to a solution of one in six hundred, the microbe can live and grow in it for months. Since the chief condition of attenuation consists in the absence of spores, this condition seems to be realized by the culture in a solution of carbolic acid, one in nine hundred, and it is probable that a fresh form of attenuated virus may thus be obtained. Diluted sulphuric acid gives analogous results.

However this may be, the vaccine prepared by Pasteur's process is the only one which has been largely used, and which has afforded certain results to cattle-breeders.

Public experiments, performed before commissions composed of most competent men, have clearly shown the virtue of the protective action. In the summer of 1881, the initiation was taken by the Melun Society of Agriculture. Twenty-five sheep and eight cows or oxen were vaccinated at Pouilly-le-Fort, and then re-inoculated with blood from animals which had recently died of anthrax, together with twenty-five sheep and five cows which had not been previously vaccinated. None of the vaccinated animals suffered while the twenty-five test sheep died within forty-eight hours, and the five cows were so ill that the veterinary surgeons despaired of them for several days.

This experiment was publicly repeated in September, 1881, by Thuillier, Pasteur's fellow-worker, whose death we have recently had to deplore, before the representatives of the Austro-Hungarian Government; and again near Berlin, in 1882, before the representatives of the German Government, and always with the same success. Up to April, 1882, more than 130,000 sheep and 2000 oxen or cows had been vaccinated; and since that time the demand for vaccine from Pasteur's laboratory has reached him from every quarter.

III. Fowl Cholera.

The sickness of barn-door poultry, which is commonly called cholera, is caused by the presence in the blood of a small micrococcus or bacterium in the form of the figure 8, differing, therefore, in form from *Bacillus anthracis*, but also an aërobie. It may be cultivated in chicken-broth, neutralized by potash, while it soon dies in the extract of yeast, which is so well adapted to *Bacillus anthracis*.

The microbe of this disease may also be attenuated by culture, and it may be done more easily than in the case of anthrax, since it is not necessary to raise the temperature, as the bacterium of fowl-cholera does not produce spores under culture. Pasteur has therefore been able to prepare an attenuated virus well adapted to protect fowls from further attacks of this disease.

IV. Swine Fever.

The disease affecting swine, which is called *rouget*, or swine fever, in the south of France, has been recently studied by Detmers in the United States, where it is also very prevalent, and by Pasteur in the department of Vaucluse. It is a kind of *pneumo-enteritis*.

These observers consider that the disease is caused by a very slender microbe, formed, like that of fowl-cholera, in the shape of the figure 8, but more minute. Others say that there is a bacillus which was observed by Klein as early as 1878 in swine attacked by this disease. In spite of the apparent contradiction, it is probable that we have only two forms of the same microbe, for the bacillus in Klein's culture at first resembles *Bacterium termo,* in the form of an 8, before it is elongated into rods.

Pasteur has succeeded in making cultures of microbes in the figure 8. He has inoculated swine with the attenuated form, after which they have been

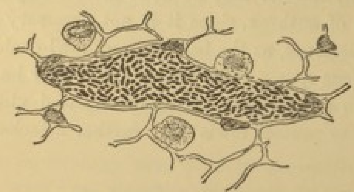


Fig. 70.—Swine fever: section of a lymphatic gland, showing a blood-vessel filled with microbes (much enlarged: Klein).

able to resist the disease, so there is reason to hope that in the near future this new vaccine, containing the attenuated microbe, may become the safeguard of our pig-sties.

V. Of some other Diseases peculiar to Domestic Animals.

An epidemic which raged in Paris in 1881 was called the typhoid fever of horses, and was fatal to more than 1500 animals belonging to the General Omnibus Company in that city. This disease is also produced by a microbe, with which Pasteur was able to inoculate other animals (rabbits); for this purpose he made use of the serous discharge from the horses' nostrils. The inoculated rabbits died with all the symptoms and lesions characteristic of the disease.

The attenuation of this microbe by culture is difficult, since at the end of a certain time the action of the air kills it. Pasteur has, however, found an expedient by which to accomplish his purpose. When the culture is shown to be sterile in consequence of the death of the microbe, he takes as the mother culture of a fresh series of daily cultures the one which was made on the day preceding the death of the first mother culture. In this way he has obtained an attenuated virus with which to inoculate rabbits, and the same result might undoubtedly be obtained in the case of horses.

There are many other contagious diseases which affect domestic animals, and which are probably due to microbes, such as, for instance, the infectious pneumonia of horned cattle. This was probably the first disease in which the protective effects of inoculation were tried according to Wilhelm's method. This method consisted in making an incision under the animal's tail with a scalpel dipped in the purulent mucus or blood taken from the lung of a beast which had died of pneumonia; sometimes the serous discharge from the swelling under the tail of an inoculated animal was used for others. Fever and loss of appetite ensued, lasting from eight to twenty-five days, but the animal was afterwards safe from further attacks of the disease.

Cattle plague, or contagious typhus, is likewise ascribed to the presence of a microbe with which we are as yet imperfectly acquainted.

Experimental septicemia is entitled to special mention, since it has too often been confounded with anthrax, and has been unskilfully produced with the intention of vaccinating animals in accordance with Pasteur's process. This occurs when too long an interval (twenty-four hours) elapses after the death of

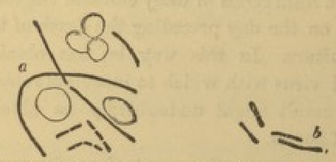


Fig. 71.—*Septic vibrio*, bacillus of malignant œdema (Koch): *a*, taken from spleen of guinea-pig; *b*, from a mouse's lung.

an animal, before taking from it the blood intended for vaccine cultures. After this date the blood no longer contains *Bacillus anthracis*, which is succeeded by another microbe termed *Vibrio septicus*, differing widely from the anthrax microbe in form, habit, and character (Fig. 71). *Bacillus anthracis* is straight and immobile, while the septic vibrio is sinuous, curled, and mobile. Moreover, it is anaërobic, and does not survive contact with the air, but it thrives in a vacuum or in carbonic acid. Since *Bacillus anthracis* is, on the other hand, an aërobie, it is clear that the two microbes cannot exist simultaneously in the blood or in the same culture liquid.

The inoculation with this fresh microbe is no less fatal; its action is even more rapid than that of *Bacillus anthracis*, but the lesions are not the same; the spleen remains normal, while the liver is discoloured.

The septic vibrio is only found in minute quantities in the blood, so that it has escaped the notice of many observers. It is, however, found in immense numbers in the muscles, in the serous fluid of the intestines, and of other organs. It is very common in the intestines, and is probably the beginning of putrefaction.

VI. Rabies.

Rabies is a canine disease which is communicated by a bite, and the inoculation of man and other animals by the saliva. We are not yet precisely acquainted with the microbe which causes the disease, but Pasteur's recent researches have thrown considerable light on its life-history, which is still, however, too much involved in obscurity.

It must first be observed that the hypothetical microbe of rabies, which no one has yet discovered, should not be confounded with the microbe of human saliva; this is found in the mouths of healthy persons, and will be briefly discussed in the following chapter.

The following conclusions are the result of Pasteur's researches into the virus of rabies.

This virus is found in the saliva of animals and men affected by rabies, associated with various microbes. Inoculation with the saliva may produce death in three forms: by the salivary microbe, by the excessive development of pus, and finally by rabies.

The brain, and especially the medulla oblongata, of men and animals which have died of rabies, is always virulent until putrefaction has set in. So also is the spinal cord. The virus is, therefore, essentially localized in the nervous system.

Rabies is rapidly and certainly developed by trephining the bones of the cranium, and then inoculating the surface of the brain with the blood or saliva of a rabid animal. In this way there is a suppression of the long incubation which ensues from simple inoculation of the blood by a bite or intra-venous injection on any part of the body. It is probable that in this case the spinal cord is the first to be affected by the virus introduced into the blood; it then fastens on its tissues and multiplies in them.

As a general rule, a first attack which has not proved fatal is no protection against a fresh attack. In 1881, however, a dog which had displayed the first symptoms of the disease of which the other animals associated with him had died, not only recovered, but failed to take rabies by trephining, when re-inoculated in 1882. Pasteur is now in possession of four dogs which are absolutely secured from infection, whatever be the mode of inoculation, and the intensity of the virus. All the other test dogs which were inoculated at the same time died of rabies. In 1884, Pasteur found the means of attenuating the virus. For this purpose he has inoculated a morsel of the brain of a mad dog into a rabbit's brain, and has passed the virus proceeding from the rabbit through the organism of a monkey, whence it becomes attenuated and a protective vaccine for dogs. This is the first step towards the extinction of this terrible disease.

VII. Glanders.

This, again, is a disease easily transmitted from horses to man. Glanders, or farcy, is caused by the presence of a bacterium, observed as early as 1868 by Christot and Kiener, and more recently studied at Berlin by Schütz and Löfler. This microbe appears in the form of very fine rods (*bacillus*) in the lungs, liver, spleen, and nasal cavity. Babès and Havas found this bacillus in the human subject in 1881. Experimental cultures have been made simultaneously in France and Germany, and have given identical results.

Bouchard, Capitan, and Charrin made their cultures in neutralized solutions of extract of meat, maintained at a temperature of 37°. By means of successive sowings, they have obtained the production of unmixed microbes, presenting no trace of the original liquid, and this was done in vessels protected from air-germs. These cultures may be carried to the eighth generation.

Asses and horses inoculated with liquid containing the microbes produced by this culture have died with the lesions characteristic of glanders (glanderous tubercles in the spleen, lungs, etc.). Cats and other animals which have been inoculated in the same way die with glanderous tubercles in the lymphatic glands and other organs.

It follows from these experiments that the microbe which causes this disease is always reproduced in the different culture liquids with its characteristic form and dimensions; that uni-ungulates can be inoculated with it, as well as man and other animals. In fact, this microbe is the essential cause of the disease.

VIII. Pebrine and Flacherie, Diseases affecting Silkworms.

We have already spoken of muscardine, a silkworm's disease produced by a microscopic fungus; two other diseases are caused by distinct microbes, of which we must shortly speak.

Pebrine.—In the silkworm nurseries, in which this disease prevails, the silkworms which issue from the eggs, technically called seed, are slowly and irregularly developed, so as to vary greatly in size. Many die young, and those which survive the fourth moult shrink and shrivel away; they can hardly creep on to the heather to spin their cocoon, and produce scarcely any silk.

On an examination of the worms which have died of this disease, De Quatrefages ascertained the presence of minute stains on the skin and in the interior of the body, which he compared to a sprinkling of black pepper; hence the name pebrine. Under the microscope these stains assume the form of small mobile granules like bacteria, which Cornalia termed vibratile corpuscles, on account of their movements. Finally, Osimo and Vittadini ascertained the existence of these corpuscles in the eggs, and consequently showed that the epidemic might be averted by the sole use of healthy eggs, of which the soundness should be established by microscopic examination.

It was at about this date, 1865, that Pasteur undertook the exhaustive study of pebrine; but Béchamp was the first to pronounce the disease parasitic, resembling muscardine in this respect, and caused by the attacks of a microbe—or microzyma, to adopt Béchamp's name—of which the germ or spore is derived from the air, at first attacking the silkworm from without, but multiplying in its interior, and developing with its growth, so that the infected moth is unable to lay its eggs without depositing the spores of the microbe at the same time, and thus exposing the young grub to attack as soon as it is born. Pasteur's own researches soon induced him to adopt the same view.

The pebrine microbe was long regarded as a true bacterium, successively described as *Bacterium bombycis*, *Nosema bombycis* (Fig. 72), and *Panistophyton ovale*. Balbiani's recent researches tend to show that it should be assigned to another group, much nearer to animals, and designated *Sporozoaria*.

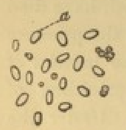


Fig. 72. — *Nosema bombycis*, pebrine microbe (× 500 diam.).

Sporozoaria.—These protista, still regarded as plants by many naturalists, chiefly differ from bacteria by their mode of growth and reproduction, in which they resemble the parasitic protozoaria, termed *Psorospermia*, *Coccidies*, and *Gregarinidæ*.

In *Sporozoaria*, growth by fission, the rule in all bacteria, has not been observed; this distinction is fundamental. Sporozoaria multiply by free spore-formation in a mass of sarcode substance (protoplasm), resulting from the encysting of the primitive corpuscles (mother-cells). The formation of numerous spores may be observed within the mother-cells, having the appearance of *pseudonavicellæ* or spores of gregarinidæ and psorospermia (parasites of vertebrate animals). Balbiani forms these organisms, which are found in many insects, into a small group, which he terms *Microsporidia*.

The ripe spores are the vibratile corpuscles of

Cornalia. They closely resemble the spores of some bacilli (*B. amylobacter*, for instance), and their germination is likewise effected by perforation of the spore at one end, and issue of the protoplasm from the interior. This, however, does not issue in a rod-like form (*Bacillus*), but in that of a small protoplasmic mass, with amœboid movements, a characteristic not observed in any bacterium (Balbiani).

The other species of silkworms which have been recently introduced, notably the oak silkworm from China (*Attacus Pernyi*), are attacked by microsporidia analogous to those of pebrine.

Pasteur has indicated the mode of averting the ravages of this disease. He has thus addressed the breeders: "If you wish to know whether a lot of cocoons will yield good seed, separate a portion of them and subject them to heat, which will accelerate the escape of the moth by four or five days, and examine them under the microscope to ascertain whether corpuscles of pebrine are present. If they are, send all the cocoons to the silk factory. If they are not diseased, allow them to breed, and the seed will be good and will hatch out successfully. In a word, start with absolutely healthy seed, produced by absolutely pure parents, and rear them under such conditions of cleanliness and isolation as may ensure immunity from infection."

When the disease is developed, fumigation with sulphurous acid is recommended, or preferably with creosote or carbolic acid, which do not affect the silkworms (Béchamp), and which hinder the development of microsporidia. These fumigations likewise keep the litter from becoming corrupt, and in a properly conducted nursery the litter is kept dry.

Flacherie.—Wrongly confounded with pebrine, the disease *flacherie* is still more destructive to silkworms. The symptoms are remarkable. The rearing of silkworms often goes on regularly up to the fourth moult, and success seems assured, when the silkworms suddenly cease to feed, avoid the leaves, become torpid, and perish, while still retaining an appearance of vitality, so that it is necessary to touch them in order to ascertain that they are dead. In this state they are termed *morts-flats.* A few days, sometimes even a few hours, suffice to transform the most flourishing nursery into a charnel-house.

Pasteur examined these *morts-flats,* and found that the leaves contained in the stomach and intestine were full of bacteria, resembling those which are developed when the leaves are bruised in a glass of water and left to putrefy (Fig. 73). In a healthy specimen, of good digestion, these bacteria are never found. It is therefore evident that the disease is owing to bad digestion, and becomes rapidly fatal in animals which consume an enormous amount of food, and do nothing but eat from morning to night. The digestive

Fig. 73.—*Micrococcus bombycis* (Cohn), *Flacherie* microbe (× 500 diam.).

ferments of unhealthy silkworms do not suffice to destroy the bacteria of the leaves, nor to neutralize their injurious effects.

These bacteria are really the cause of the disease, for if even a minute quantity of the leaves taken from the intestine of diseased silkworms be given to healthy specimens, they soon die of the same disease. It is, therefore, essentially contagious, and in order to prevent the diseased silkworms from contaminating the healthy by soiling the leaves on which the latter are about to feed, as much space should be assigned to them as possible.

Good seed should also be selected, since it has been ascertained that some lots of seed are more liable to the disease than others. The affection does not indeed begin in the egg, as in pebrine, but the question of heredity comes in. It is clear that when a silkworm has been affected by *flacherie* without dying of it, its eggs will have little vitality, and the grubs which issue from them will be predisposed by their feeble constitution to contract the disease.

CHAPTER V.

THE MICROBES OF HUMAN DISEASES.

I. Microbes of Air, Earth, and Water.

It is generally admitted that the large majority of epidemic and contagious diseases which affect men and animals are caused by the introduction of certain kinds of microbes into the organism. In reply to the question how these microbes are introduced into the body, and where they are before entering it, it is easy to show that these microbes exist in immense numbers —they or their spores—in the air we breathe, in the water we drink, in the ground on which we tread, and whence there rises, whenever it is dry, a fine dust charged with all sorts of germs, which penetrate together with the air into our mouths and lungs.

For a long while we were almost completely ignorant of the conditions of existence of these microbes when they are in the soil or water. The recent researches of Zopf, a German botanist, tend to show that among the inferior algæ termed Bacteria or Schizophyta, there is a very remarkable dimorphism of mode and habitat. In *Beggiatoa* of sulphurous waters, for instance, and in *Cladothrix*, which forms a whitish pellicle on the surface of putrefying liquids, Zopf has found, under certain conditions, all the forms designated as Micrococcus, Bacillus, Leptothrix, and Bacterium; that is, microbes strictly so called, including those which are the producing agents of contagious diseases.

Where these algæ are found in water or on a damp soil, conditions of existence favourable to their development, there they live and multiply. But when the soil dries up, when a river returns to its bed after a flood, or a marsh disappears in consequence of the evaporation of its waters, all these algæ give forth dormant spores, destined to ensure their propagation. We have described the formation of these spores by concentration of the protoplasm in the interior of each cell; in this form their volume is very small, and they are extremely light, so that as soon as they are desiccated, and then only, these spores are carried away by the slightest breeze and borne to great distances. These are termed air-germs.

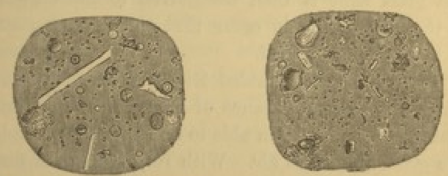
When these moving germs encounter a favourable medium, at once moist and warm, such as the human mouth or lungs, they fasten there and are immediately developed, first in the form of *Micrococcus*, then of that of *Bacterium*, *Bacillus*, or *Leptothrix*, according to the species to which the spore in question belongs.

Schizophyta may therefore have two very different modes of existence, comparable to the heteræcia (change of habitat) and dimorphism of the fungi *Ascomycetes* and *Basidiomycetes*. Schizomycetes however, although, like fungi, they obtain their nourishment from organic substances which have been already elaborated, are not true parasites in the first stage of their existence, during which stage they live freely in the water, or on the damp soil. They become true parasites when they penetrate into the blood and tissues of man, in which they necessarily live at the expense of their host.

Hence it may be seen why half-dried marshes, meadows from which a river has retreated in order to return to its bed, great excavations of the soil necessary in railway-cuttings, etc., become the source of a large number of epidemic or contagious diseases. In all these places the subsiding waters have left *Schizophyta*, or microbes in a dried state, and these are soon transformed into dormant spores, which are diffused through the air and enter the mouth and lungs of men living near the rivers and marshes, or who are working on the railway-cutting. The soil which has remained undisturbed for a long while is full of dormant spores, drawn into it by the rain to a greater or less depth; these may preserve their vitality for many years, waiting for the favourable medium which leads to their fresh development.

An acquaintance with air-germs, with the microbes of earth and water, has therefore become indispensable to the physician and to the professor of hygiene, who are anxious to decide on the precise cause of great epidemics in order, if possible, to foresee and avert them. This new branch of meteorology has been termed atmospheric micrography, since it necessarily involves the use of the microscope.

The Microbes of the Atmosphere.—In the observatory of Montsouris, Paris, there is now a special laboratory under the direction of Miquel, with the object of studying the living organisms of the air, of establishing statistics of their times and seasons,



Figs. 74, 75.—Microbes and spores of atmospheric dust, mixed with amorphous particles, and collected by the aëroscope.

and of drawing general conclusions as to the hygienic condition of the air, according as it is more or less charged with the microbes and spores which are factors of disease. This laboratory is provided with the apparatus necessary for such kinds of research.

The first of these apparatus serves to collect the living organisms which are always mingled with a large amount of inert dust (Figs. 74, 75). The apparatus is founded on the principle of the aëroscope, invented by Pouchet for the examination of air-dust. It consists of a small cylinder in which a current of air is produced by means of an aspirator, on which running water acts, similar to those in use in all laboratories of physics and chemistry. A thin plate of glass, which has on it a layer of glycerine, is placed at the bottom of the cylinder, so as to intercept the current of air and arrest the dust. The apparatus employed by Miquel at Montsouris is only a modification and improvement of the one devised by Pouchet. The glass slide is then transferred to the objective of the microscope in order that the dust deposited on it may be examined.

This process has enabled Miquel to define the laws which rule the appearance of microbes in the atmosphere, and he has been able to calculate their number in a given volume of air. With respect to such fungi and algæ as live in our houses (moulds), and on our roofs, walls, and on damp ground (such algæ as *Penicillium, Protococcus, Chlorococcus,* etc.), he has arrived at the following results, as far as Montsouris, the site of his experiments, is concerned.

Few in number in January and February, the number of mould-spores further diminishes in March, and rises again in April, May, and June, in which month the maximum is attained. The decrease is slow up to October, more marked in November, and the minimum is observed in December. In this case the influence of rain and damp is very marked. In winter the average number of spores in every cubic metre of air does not exceed 7000, while in June it rises to 35,000.

In summer, however, when the temperature is very high, the number of spores is not great; for this reason, that, in spite of the heat, the air is moist, and the spores settle on the ground, plants, or other objects, instead of floating in the air. On the other hand, in winter, since very cold weather is generally dry, the number of air-germs increases.

In summer, storms only purify the air for a very short time; within fifteen or eighteen hours after the rain, the germs reappear, and are five to ten times more numerous than before. It seems that storms give an energetic impulse to the production of moulds.

If we turn to consider microbes, strictly so called, or the bacteria which are the causes of malignant diseases, research becomes more difficult, on account of their smaller size and great transparency. An expedient is necessary to reveal their presence and enable us to count them accurately: this expedient consists in staining them by various processes, of which we shall speak when we come to discuss the micrographic study of drinking-water. Miquel prefers the process of filtration of the air invented by Pasteur, which consists in passing the air and aqueous vapour into such sterilized liquids as are favourable to the nutrition of microbes.

Sterilized Flasks.—Pasteur has shown that air may be deprived of all its germs by being passed through a capillary tube, turned back upon itself. He takes a glass flask and draws out its neck so as to form a long tube, which is bent in different directions (Fig. 76). The prolonged application of heat expels the air contained in the flask, which is therefore sterilized, and it is then allowed to cool slowly. A

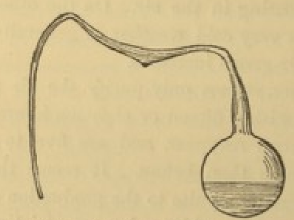


Fig. 76.—Pasteur's flask, with bent tube, containing a culture liquid, sterilized.

hot culture liquid may now be put into the flask. It must be ascertained, by keeping the flask at a temperature of 36° for several days, that the liquid is completely sterilized. The culture flasks are thus fitted to receive the air which is to be the object of study, together with the spores contained in it.

Culture liquids.—There is a considerable variety of culture liquids: Pasteur's mineral solution, infusion of hay or turnips, neutral urine, chicken-broth, beef-tea, etc. They should be plunged in a bath heated to a temperature of 150° to 180°, since some spores are capable of resisting a prolonged boiling at a temperature of 100°; they still live and are capable of germinating and multiplying when the liquid is cooled.

Culture liquids may also be sterilized without the use of heat, which to some extent affects their nature, by filtering them through a porous substance—biscuit-ware, or a mixture of plaster and amianthus, etc. A more perfect apparatus is employed by Miquel, consisting of a filter of very thick paper, through which the liquid is forced by the simultaneous action of a vacuum on one side, and of strong pressure on the other.

For the artificial culture of microbes, solid or partially solid substances are by preference often used, such as gelatine, or slices of potâtoes, carrots, hard eggs, etc., prepared in different ways and sterilized before use. We cannot here describe in detail all the processes employed and the precautions necessary in order to avoid error. We must content ourselves with giving the results obtained by Miquel.

There are on an average 80 bacteria in a cubic metre of Montsouris air. A hundred of these bacteria includes 66 *Micrococci*, 21 *Bacteria* and 13 *Bacilli*. In rain water there is a different proportion: 28 *Micrococci*, 9 *Bacteria*, 63 *Bacilli*. At the beginning of a thunderstorm, the rain-water includes a considerable number, about 15 to the cubic centimetre; then the number diminishes, but Miquel states that "after two or three days of damp, rainy weather, the rain-water often contains more bacteria than when it began to fall. Since the atmosphere is then excessively pure, it seems that the bacteria are able to live and multiply in the clouds, or else that the clouds, in their passage through space, take up a varying contingent of germs."

The maximum of air-germs is observed in autumn, the minimum in winter; thus, 50 bacteria were counted in December and January, only 33 in February, 105 in May, 50 in June, and 170 in October.

Inversely to what occurs with moulds, the number of bacteria, low in rainy weather, rises when all moisture has disappeared from the surface of the soil. The effect of dryness is greater than that of warmth. This explains the scarcity of bacteria after the great rains of February, April, and June. A long drought is, however, unfavourable to their development.

Miquel's experiments lead him to conclude that dew, the evaporation from the soil, is never charged with spores. The dry dust in the neighbourhood of inhabited places, and especially of hospitals, is, on the other hand, charged with microbes. In the centre of Paris, for example, in the Rue de Rivoli, there are nine or ten times as many microbes in the atmosphere as in the neighbourhood of the fortifications. In the Montsouris Observatory, south of Paris, the north winds bring many more bacteria than the south winds. The most impure wind comes from the hills of Villette and Belleville, crowded and populous quarters, in which are also cemeteries and slaughter-houses.

It has long been established that the air is much purer on high mountains or on the sea, than in plains and in the vicinity of inhabited places. If glass flasks which have been previously sterilized and deprived of air are taken to a great height on the Alps or Pyrenees, and then filled with air, it will be difficult to detect any microbes, and the few which may be found are possibly brought by the observer. So again, on the top of the Pantheon, a cubic metre of air only contains 28 microbes, while 45 are found in the park of Montsouris, and 462 in the centre of Paris.

The Microbes of Running and Drinking Water.—Water, whatever be its source, contains many more microbes than air. They are even found in spring-water taken from its source, which shows that they exist in the interior of the earth. The following is Miquel's estimate, which will give an idea of the quantity of microbes found in Paris water, taken from different places:—

Source of water.	No. of microbes to the litre.
Condensed aqueous vapour	900
Water from drain, Asnières	48,000
Rain-water	64,000
Vanne water (Montrouge basin)	248,000
Seine water (from Bercy, above Paris)	4,800,000
Seine water (from Asnières, below Paris)	12,800,000
Sewer-water (from Clichy)	80,000,000

These numbers are the minima. The putrefaction of stagnant sewer-water produces germs from which, in a few days, microbes are multiplied by thousands.

Certes, in France, and Maggi, in Italy, have lately been occupied with the micrographic study of drinking-water. These observers reveal the presence of microbes in the water under examination by means of staining reagents. The reagent most in use is a 1·5 per cent. solution of osmic acid (Certes). Osmic acid kills the microbes without changing their form, and precipitates them to the bottom of the glass vessel, whence it is easy to collect them. A cubic centimetre of the solution suffices for 30 or 40 cubic centimetres of water. It is allowed to settle, then the liquid is poured off, and the thick, dark-coloured deposit which remains consists of all the organisms previously diffused in the liquid, and may be examined under the microscope. The only drawback to the use of this reagent is the high price of osmic acid, a matter worth consideration in the extensive and comparative researches necessary in these cases. Maggi obtained analogous results with chloride of palladium, and Certes with iodide of glycerine, and alcoholic solutions of cyanine, gentian, etc.; but none of these reagents are as efficient as osmic acid, of which the effect is more precise, constant, and durable.

Microbes of the Soil.—The presence of microbes in the soil has been proved by Pasteur and his fellow-workers, Chamberland and Roux, in the researches into the nature of anthrax, of which we have spoken above. These observers collected earth in the neighbourhood of trenches in which animals which had died of anthrax had been buried, and found that not only on the surface, but at some depth, this earth was full of bacteridia (*Bacillus anthracis*), and also of many other microbes or germs, of which the inoculation might produce more or less dangerous diseases in animals. In order to procure earth in a more perfect state of division, it occurred to Pasteur to collect the excrement of earthworms, which consists almost exclusively of clay, rich in humus or vegetable earth, on which the worms are nourished. This earth, after passing through the intestinal canal of worms, still contains microbes which have not lost their virulence. As we have already said, spring water, on issuing from the soil, contains microbes which it has acquired in filtering through geological layers; and we have also mentioned the living microbes of chalk, dating, as Béchamp believes, from the secondary epoch.

Telluric and Diblastic Theories.—Hence, it is intelligible that a theory should have been formed, ascribing most epidemic diseases to the influence of microbes of the soil, which can at a given moment enter the human body, first by penetrating into the lungs and digestive organs, and thence into the blood.

Two German discoverers, Pettenkofer and Nägeli, set forth this telluric theory of disease, and several facts confirm it. It explains why intermittent fever or malaria only prevails in marshy countries when the marshes are partially dry, and especially in summer. In order to make such country healthy, the marshes must be completely dried and filled up, and then transformed into cultivated ground. So, again, the river valleys in France only become unhealthy when the stream returns to its bed, leaving the adjoining meadows transformed into marshes, which gradually dry up and send forth into the air a host of spores, produced by the schizophyta deposited by the water. Finally, great excavations of earth diffuse through the atmosphere the dormant spores brought thither by rain, and remaining in a desiccated state in the soil.

In many cases, the intervention of two microbes of different kinds have been assumed to explain the nature and progress of great epidemics, such as cholera, yellow fever, and typhoid fever. This is termed by Nägeli the diblastic theory (or that of two producing agents of disease). Thus the microbe of malaria, or intermittent fever, which is not contagious, often predisposes the patient to receive the attacks of another zymotic disease, such as cholera or typhoid fever. The two microbes may subsist simultaneously in the human frame, and their joint action may weaken the organism at the expense of which they live and multiply. Numerous cases might be cited to support this theory, and the following examples may be given:—

"In the summer and autumn of 1873 the town of Spires was visited by cholera, which was limited to the lower part of the town, situated on the banks of the Speyerbach. There was a hospital for old men, situated in the high part of the town, a quarter which remained free from cholera, but 24 out of the 200 pensioners whom the hospital contained were attacked by the disease. Now 33 of these men, the most able-bodied among them, had been employed to dig up some blighted potatoes in a field which lay very low, almost on a level with the water which had collected in a deserted sand-pit. They had not drunk of the water in this field, neither had they passed through the part of the town visited by the epidemic: 20 out of these 33 men had cholera, and only 4 others out of all the inmates of the hospital contracted the disease" (Nägeli).

Observations made on board English transports on the voyage from India give analogous results. "Detachments of equal number from two regiments embarked on the same steam transport. A few days later, cholera declared itself and carried off many soldiers, all belonging to one of the two regiments, and coming from a camp in which there was a violent outbreak of cholera shortly after their departure. The detachment from the other regiment, coming from a place exempt from cholera, altogether escaped." Here the influence of the locality and the soil is evident; it was the sole and essential agent of the disease, since the contagion could not have occurred on board ship, in which the conditions are generally healthy, neither by contact with the men, nor by that with the clothes and baggage, which were mixed together. The cholera microbe which had been brought on board ship could only act on the detachment miasmatically predisposed by their previous residence in an unhealthy place, containing the malaria microbe (Nägeli).

Miasma and Microbes.—This leads us to say a few words on the term miasma, formerly in such common use, and now without meaning. Before the existence of microbes and air-germs was known, the doubtful and mysterious principles which were believed to be the cause of virulent and contagious diseases were termed miasmata, and these miasmata were generally supposed to be gases. It is now proved that this cause resides in solid, living particles, the microbes and their germs: the term miasma is less and less employed, or serves to designate air-germs. When, therefore, Nägeli uses the word, he regards it as synonymous with microbes or air-germs.

The Question of Privies.—Hence it follows that it is erroneous to apply the name of miasmata to true gases, some of which exert an injurious influence on the human system. Such are sulphuretted hydrogen and ammonium sulph-hydrate which are disengaged from privies, and produce the disease called *plomb* in the men employed to empty them. These gases are deleterious to microbes as well as to men; microbes cannot co-exist with them, which is perhaps the reason why these men seem to enjoy an immunity from most contagious diseases.

People are too much disposed, when an epidemic is prevalent, to accuse the privies, of which the emanations are, under ordinary circumstances, only offensive to the smell. When these places, as well as the sewers, are properly constructed, they present no danger. But it is necessary that there should be a sufficient flow of water in both to cover the solid matter. We know, in fact, that if microbes are present, they only become dangerous when dry enough to float in the air.

In an epidemic of typhoid fever, for instance, the soiled body and bed linen of the patient are much more dangerous than the privies, in which, however, there is a much larger number of microbes. The linen, therefore, as well as the contaminated rooms and furniture, should be immediately disinfected in the mode prescribed by sanitary authorities.

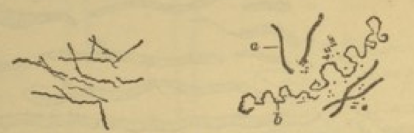
The system of directing everything to the sewer, which is now universally applied to large towns, and which has encountered much opposition, is certainly excellent when properly understood and applied. The cesspools, as well as the cemeteries, ought to be as remote as possible from the houses of the living. It is as much opposed to public health to retain cesspools which are gradually filled in the course of years, in the midst of a town, as to have intramural cemeteries. Everything should be carried off by the sewer, provided there is a sufficient flow of water to take all solid matters with it and completely cover them. These are deposited in places assigned for them, which must necessarily be very remote from thickly populated places. When these matters are then spread over a large surface to dry in the air, the oxygen becomes, as Pasteur has said, the great purifier of microbes.

In Paris, some of the sewage water of the great main sewer is diverted on to the peninsula of Gennevilliers, and it is then directed into gutters to serve as a manure for market gardens. After filtering through the cultivated plots, the water flows off in a limpid stream.

Cornilleau, whose medical practice is at Gennevilliers, has recently issued a report, showing plainly that the sewage is but a slight source of danger to the inhabitants of the peninsula. During the serious outbreak of typhoid fever which occurred in Paris in 1882, there were only two typhoid cases in the whole commune, and these cases were imported from Paris.

II. Microbes of the Mouth and Digestive Canal in a Healthy Man.

Since there is a profusion of microbes in the air, we can easily understand why they should be found in the human mouth, and hence in all parts of the digestive canal. They are for the most part harmless, as long as the epidermis of the mucous membrane covering the intestinal canal is healthy. Pasteur has shown that they are not found in the blood of a healthy man, but that the slightest lesion of the mucous membrane suffices to introduce them into the circulation.* This fact was proved by experiments made at Pouilly-le-Fort on sheep, inoculated with the anthrax microbe by means of their food. The mortality among these animals was notably increased when



Figs. 77, 78.—*Spirochæte buccalis*, and *S. plicatilis*, *b* (mixed with *Vibrio rugula*, *a*), microbes in mouth of a healthy man.

thistles, bearded grain, or sharp-edged leaves were mixed with their food, so as to cause little wounds in their mouths, each of which served as an entrance for microbes. As long as the microbes are few in number, they perish quickly in the blood; but when the number is considerable, the organism has not the power to destroy them; they soon compete with the corpuscles of the blood, and the most serious diseases ensue.

Miquel estimates the number of spores introduced into the human system by respiration, when the health

* This is not the case with fishes. Richet and Ollivier have shown that microbes are normally found in the blood of sea-fish, without affecting their health.

is perfectly sound, at 300,000 a day, and 100,000,000 a year. It is evident that these germs, always present, may easily become the source of diseases, of which thrush in the mouth of infants, and of sick and dying adults, is one of the least alarming.

Sternberg, surgeon of the United States army, 1880, writes: "When I was occupied in the micro-

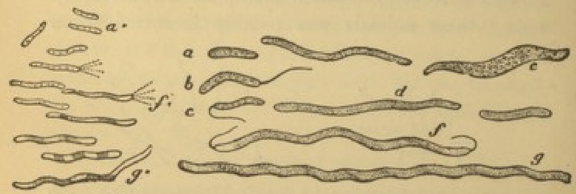


Fig. 79.—*Vibrio rugula* (Warming) in different stages of development: *b, c, f,* individuals with vibratile cilia (*flagellum*); *f'*, ciliated spores. Found in the human mouth and intestines.

scopic examination of foul river water at New Orleans, I used to find in my own mouth almost all the organisms which were present in the putrefying liquid I was examining—*Bacterium termo, Bacillus subtilis* (Fig. 80), *Spirillum undulatum,* and a variety of minute spherical forms and of rods, difficult to classify except under the generic names of *Micrococci* and *Bacteria.* Another organism which I have often found in healthy human saliva is a species of *Sarcina,* perhaps identical with *S. ventriculi.*"

But the organism most commonly found in the human mouth, which attracts attention from its large size and its abundance, is *Leptothrix buccalis.* It is never absent from the rough surface of the tongue or the interstices of the teeth, and even those persons who make a frequent use of the tooth-brush are not exempt from it. In the latter case, however, it only appears in the form of short, scattered rods; while in

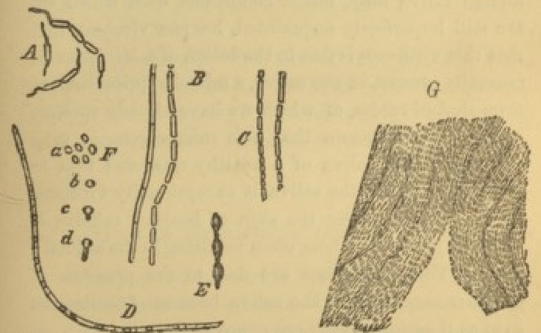


Fig. 80.—*Bacterium* (*Bacillus*) *subtilis* (Zopf), in different stages: *A*, ciliated rods; *E*, *F*, spores; *G*, *Zooglœa*. In infusions of hay, and in the human mouth (much magnified).

other cases, the tufted stems of its vigorous growth abound in the saliva, and are often established on the epithelial cells, whence they may be detached by friction.

Sternberg compares the human mouth to a culture apparatus, in which the germs of microbes find an even temperature and the moisture necessary for their development naturally provided for them—conditions which can only be artificially produced in the laboratory.

III. The Virulent Microbe of Healthy Human Saliva.

Pasteur and Vulpian in France, and Sternberg in America, discovered almost simultaneously that the human saliva may, under conditions with which we are still imperfectly acquainted, become virulent, and that this virulence is due to the action of a *Micrococcus*, normally present in the saliva, a microbe quite distinct from that of rabies, of which we have already spoken.

It is only known that this micrococcus is very common in the saliva of a healthy man, and that in some individuals the saliva is exceptionally virulent. When injected under the skin of healthy rabbits, it produces grave affections, often resulting in the animal's death. These affections are due to the presence of the micrococcus, since the saliva becomes harmless as soon as these organisms are removed from it.

Sternberg informs us that his own saliva is among those which possess this curious and alarming property. He regards the more abundant nutriment which this microbe finds in the mouths of some persons as the cause of this virulence, since thus its development is more energetic. "In my own case," he writes, "there is a very abundant secretion of saliva. . . . My culture experiments show that this micrococcus multiplies very rapidly, and in virtue of this faculty it has for a certain time the advantage over *Bacterium termo*, which appears to be fatal to the former when present in any number. . . . In my culture flasks, a small drop of blood from an infected rabbit gave birth within a few hours to such a number of microbes that the liquid contained in the flask was completely filled with them, and it was deprived of the nutriment necessary for any further development."

The exceptional virulence of this microbe must therefore be ascribed to its vital and reproductive energy, and to the rapidity with which it multiplies; at any rate, until we know more on the subject.

IV. The Microbes of Dental Caries.

Miller's recent researches (1884) tend to show that dental caries is chiefly due to the development of one or more species of bacteria. The presence of acids introduced into the mouth, or developed by certain diseases (ulcers, thrush, etc.) which are themselves produced by microbes, appears to be the predisposing cause of this affection. These acids begin by softening the dentine, deprived at some point of its superficial coating of enamel, and through this the bacteria enter. Saliva can be rendered experimentally acid by mixing it for four hours, at a temperature of 20°, with sugar and starch (Cornil). Hence the injuriousness of sugar-plums and other sweetmeats, long and correctly supposed to be the cause of the early decay of teeth, especially in children who eat them in excess.

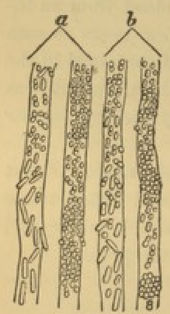


Fig. 81.—Bacterium of dental caries in the dentine tubules: *a*, artificial caries; *b*, spontaneous caries.

The microbe which Miller has found to be most common in decayed teeth is very polymorphic. *Micrococcus, bacterium*, chains and filaments, are only different phases of the same plant, which also produces acid fermentation in the mouth, and the formation of lactic acid. Within the dentine tubules, a section examined under the microscope shows all the intermediate stages between the isolated micrococcus and the filaments (Figs. 81, 82). Miller succeeded in producing this disease in sound teeth artificially.

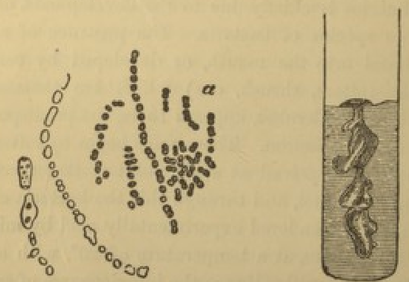


Fig. 82.—Bacterium of dental caries: *a*, *b*, different forms obtained in gelatine culture.

According to his experiments, the best dentifrice for the destruction of microbes is a solution of corrosive sublimate (mercuric chloride), one part in 1000, which can be further diluted by four parts of pure water.

V. Microbes of Intermittent or Malarious Fevers.

We say microbes in the plural, since it is almost certain that the different types of intermittent fever, tertian, quartan fever, etc., are produced by different microbes; moreover, it is probable that these microbes vary with the locality. That of intermittent fever in France is probably not the same as that of the malaria, or fever of the Pontine marshes in Italy; and the African fevers, again, are probably produced by a different organism.

Intermittent fevers are the first internal diseases of which the vegetable parasitic nature was suspected. Before that time we were only acquainted with the parasites of the skin, and with the entozoaria and epizoaria (intestinal worms, lice, acari, etc.), which are animals. In 1869, Dr. Salisbury, of Cleveland, U.S., entered on researches which led him to the conclusion that intermittent fever in the marshy valleys of the Ohio and the Mississippi must be ascribed to the presence in the system of a filamentous alga which approximates to the genus *Palmella*. The spores of this alga are constantly found in the saliva of the subjects of intermittent fever. By exposure during the night of little glass plates in marshy meadows, Salisbury was able to collect similar spores, which settled on the lower surface of the glass, and were found floating in the drops of condensed dew.* On passing through these marshes in the evening, there was a peculiar sense of dryness in the throat, and expectoration revealed the presence of spores of *Palmella*. Finally, earth taken from these marshes was found to be full of the same organisms.

When the marsh begins to dry up, the spores are produced in abundance, and intermittent fevers occur. Salisbury writes that "in 1862, the weather was very wet until about the 1st of July; but that during July, August, and September, there was hardly a drop of rain. The springs and water-courses were nearly dried up, the marshes and wet grounds also became dry, vegetation was almost completely arrested, and the whole country presented an arid appearance. Shortly after the drought began, intermittent fever made its appearance in all the unhealthy districts, and spread so rapidly during the months of July and August, that it attacked almost every family living on marshy ground.

"A low, peaty meadow extends along the canal

* We must repeat what has been said before, that the presence of these spores in the air is quite independent of that of the vapour which constitutes dew; in other words, the vapour does not transport these spores, which must, on the contrary, be perfectly dry before they can float in the air and settle on any damp object.

to the south-east of the town of Lancaster, and the neighbouring valleys are low and damp. The third quarter of the town, touching on this meadow, and all that part which is not raised from 35 to 40 feet above the level of the meadow, have always been districts in which attacks of intermittent fever are prevalent. Those who live near the marsh are liable to annual attacks of fever from May to November. In August and September these attacks are generally the most severe."

We said that moisture does not favour the transport of microbes and their spores through the air, but the remark does not apply to fogs, in which numerous spores are found. We know that fogs are formed of minute globules of water, which float in the atmosphere, and of which the vapour of our breath, only visible in cold weather, can give us an idea. These globules of water float in the air just as spores and all kinds of dust do, without wetting the spores or running together, since as soon as this occurs, the fog ceases to be; it is condensed, and falls in the form of more or less fine rain. Salisbury has ascertained that there is a certain connection between fogs and intermittent fevers, and this explains why people are more apt to contract fever in the morning and evening, at which times there is in summer always a fog floating to a varying height above marshy places. In a farm near Lancaster, the farmer and his wife, who slept on the first floor, were attacked by tertian fever, while their seven children, who slept on the second floor, escaped. Salisbury ascertained that there was a fog every morning, rising from a reservoir which had been recently made. This fog reached the house and rose above the first floor, but not as high as the windows of the second floor, and penetrated into the parents' bed-chamber through the open window. This vapour had the same smell as the marsh, which was covered with fever algæ (*Palmella febrilis*), and produced the same feverish dryness in the throat and pharynx. The vapour dispersed soon after sunrise, and before the children had left their chamber.

Salisbury likewise ascertained the polymorphism of *Palmella febrilis*, a polymorphism which is confirmed by the recent observations of the skilful naturalist Zopf, and this fact explains the mode in which an aquatic alga can live in the human blood, in the form of *Bacillus* or *Spirillum*.

Still more recently (1879), marsh fever, or malaria, which is so common in Sicily and in the Roman Campagna, have been studied from the same point of view by Crudeli, Cuboni, Cecci, and others, who ascribe the disease to a vegetable parasite which they call *Bacillus malariæ*. This bacillus is abundantly found in the blood of patients during the period of attack, while during the period of acme which terminates each attack only spores are found. The same microscopic organism is found in all the malarious districts of the Roman Campagna, and it can be produced in artificial cultures. It is not found in the healthy parts of Lombardy. In the strata of air which float above malarious ground in summer, this microbe is so common that it is found in abundance in the sweat of the forehead and hands (Fig. 83).

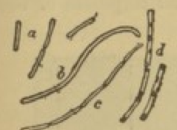


Fig. 82.—Malaria bacillus (Klebs and Cecci).

This organism is not only capable of cultivation, but rabbits and dogs can be inoculated with it, so as to produce marsh fever in them.* The lesions which are observed in an autopsy are the same as those in man, showing that the site preferred by the microbe is the spleen and the marrow of the bones.

The fact that the bacillus and its spores are successively found in the blood explains the intermittent type of the disease, tertian, quartan, etc., according to the variety of marsh fever. According to its variety, and perhaps to the species of *Schizophytum*, the complete evolution of the plant sometimes demands 48, sometimes 72 hours, and the access of fever always corresponds with the period of greatest activity in the bacillus—that which precedes the emission of spores.

Two military surgeons, Laveran and Richard,

* It is generally believed in France that animals, and especially herbivora, cannot contract intermittent fever. This opinion is erroneous. It is known that in Italy cattle contract this fever when they are not acclimatized to marshy districts, and that they are cured by sulphate of quinine.

have also observed the parasitic nature of intermittent fever in Algeria. The organism which they have constantly found in the blood of those affected by marsh fever presents several different aspects, but appears especially to attack the red corpuscle of the

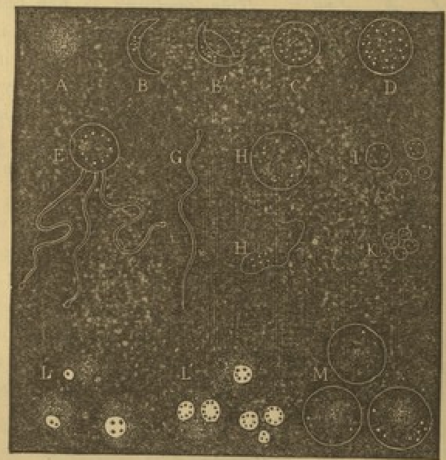


Fig. 84.—Parasite of intermittent fever (Laveran): A, normal hæmatin; B, B, corpuscle No. 1; C, corpuscle No. 2, motionless; D, corpuscle No. 2, containing mobile pigmented grains; E, corpuscle No. 2, provided with mobile filaments; G, detached mobile filament; H, H, corpuscle No. 3; I, K, corpuscle No. 2, of small size, red and agglomerated; L, L, hæmatins to which the small corpuscles No. 2 are attached; M, pigmented leucocytes, their nuclei made visible by carmine.

blood, in which, according to Laveran's expression, "it is encysted like a weevil in a grain of wheat."

This observer thinks that it approximates to the algæ of the genus Oscillaria * (Fig. 84).

The different forms taken by this organism are only the successive phases of its development, and have not yet been observed by a competent botanist, who alone can indicate precisely their true nature. At a certain period of its existence the parasite attaches itself to the red corpuscle of the blood, and is nourished at its expense. The corpuscle turns pale, loses its colouring matter, and disappears, leaving as residue a small grain of pigment, representing the hæmoglobin absorbed by the parasite. Two or three mobile filaments arise from the encysted parasite, which resemble vibrios, and move rapidly in the blood as soon as they become detached. Laveran states that he has found the same organism in malaria patients at Rome; and Richard found them in the blood of a sailor just returned from China, who was suffering from intermittent fever. The use of the microscope permits an accurate diagnosis of this disease.

The spherical bodies, or the microbe in its encysted form, announce that the attack is imminent, and no time should be lost in administering sulphate of quinine. Richard writes that "the multiplication of these bodies must be extremely rapid. For instance, in tertian fever they are not found in the intervals of the attacks (*apyrexia*). As the attack approaches,

* *Révue Scientifique*, April 29, 1882, p. 527; Januar, 27, 1883, p 113.

they appear in increasing numbers, and their maximum corresponds with the beginning of the rise in temperature; from that moment they begin to perish, since the heat of fever is fatal to them, and completely checks their development. This explains the intermittent character of the disease. They produce fever, the fever kills them and then subsides; when *apyrexia* occurs they multiply again, excite fever, and so on." Thus there is a successive series of auto-infection by the parasite itself, unless its development is arrested by sulphate of quinine. "The parasites of typhus and typhoid fever are not affected by a temperature of 40°, and even of 42°, and hence the continuous character of these fevers."

Cornil has, with some justice, criticized Laveran's description and illustrations of the parasite of marsh fever. It is difficult to recognize in it an organism really belonging to the animal or vegetable kingdom. The form of the filaments which, as he asserts, issue from the so-called encysted bodies, resemble those which Hoffmann has seen and drawn in blood in its normal state, and also in various diseases, and are probably only expansions of extravasated protoplasm in the red corpuscles at a temperature of 40°. The encysted bodies are also, according to all appearance, only blood-corpuscles, more or less affected by disease.

There only remain the pigmented, encysted granules in the red and colourless corpuscles, granules which have been observed by others, and especially by

Marchiafava and Celli. But experiments undertaken to show that these granules are microbes have as yet afforded no certain results.

In short, Cornil remarks: "Since bacteria are found neither in the internal organs nor in the blood of those who die of intermittent fever, we are tempted to suppose that the virulent agent resides in the surface of the mucous membrane—for example, in that of the digestive canal; and that the chemical poisons produced under the influence of these micro-organisms penetrate thence into the blood. They then act on the red corpuscles of the blood."

Finally, we must remember that many continuous fevers, especially those of hot countries, seem to be complicated by the presence of two parasitic elements, as we have said in describing Nägeli's diblastic theory. To the marsh microbe, which comes from the soil, another is added, of which the immediate origin is due either to direct contagion, or to some other telluric or atmospheric local influence.

VI. Recurrent Fever and Yellow Fever.

We place these two diseases together, simply because they have rarely been observed in France. Recurrent fever, or relapsing typhus, is a disease which has been observed in Germany, Russia, Ireland, and India, in which latter country it is called jungle fever. In all these countries poverty, scarcity, and famine appear to be the predisposing causes. In this case, the presence of microbes in the human blood has been established in the clearest and most incontestable way. This discovery was made by Virchow and Obermeier in 1868, but nothing was published on the subject until 1873.

The symptoms of the disease are very like those of typhoid fever. The microbe, which may always be found in the blood, and which characterizes the disease, is a *Spirillum* or *Spirochæte* (*S. Obermeieri*); that is, a filamentous organism, twisted into several spirals, and animated by very lively movements (Fig. 51, *m*, *o*). These spirilla may be seen moving in thousands among the blood-corpuscles, when these are placed under the objective of the microscope.

The difficulties experienced by the original observers in their attempts to inoculate man or animals with the disease, and the fact that in some cases the microbes appear to be absent from the blood of affected persons, have thrown some doubt on the relation between the disease and its microbe. This is because the conditions of the existence of this plant in the system were not sufficiently considered. Albrecht has recently shown (1880) that blood which apparently contains no spirilla will, if kept in a culture-flask for some days, protected from air-germs, become full of these organisms at the end of that time, a proof of the pre-existence of the spores

The same observer was able to point out the spores, which are only visible under a magnifying power of 1000 diameters, and which succeed to the spirilla during the remittent period. Moreover, a monkey was successfully inoculated with the disease at Bombay, and after the lapse of five days spirilla were found in the animal's blood.

Yellow fever has not yet been sufficiently studied in the countries in which it prevails, but there can be no doubt that it is likewise produced by a special schizophytum. Originating, as it appears, in North America, probably in the delta of the Mississippi, this disease has been spread by maritime commerce over the whole intertropical zone of the globe. The centres of infection are always on the sea-board, at the mouths of great rivers, from which we conclude that its special microbe is found in its free state in the brackish marshes formed at river-mouths.

The medical men of Rio de Janeiro, and particularly Freire, have lately described and published illustrations of microbes said to have been observed by them in the fæces of patients attacked by yellow fever. But their drawings are for the most part fanciful, and betray great inexperience in the methods of research and in microscopic examinations; for instance, the air-bubbles, unskilfully interposed in the preparations which their author thought worthy of photographic reproduction, figure as microbes. Thanks to the accuracy of photography, which leaves no scope for the fancy of a draughtsman, there can be no doubt as to the gross error committed by the observer.

As for Freire's attempts at vaccination, his own statistics are far from being favourable to his method; in fact, they prove that vaccination increased the rate of deaths in the proportion of 19 per 100.

Much more scientific researches were undertaken

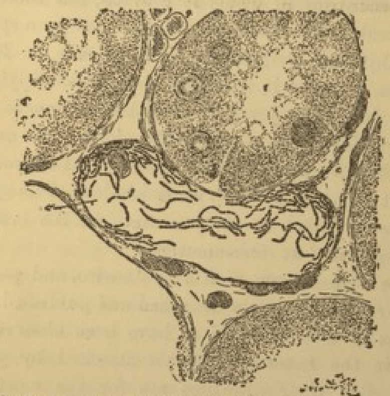


Fig. 85.—Section of Kidney in yellow fever (Babès), showing a capillary vessel, c, filled with chaplets of micrococci.

by Cornil in Paris, on some anatomical preparations, preserved in alcohol, which were sent from Brazil. He found in the liver and kidney of the victims of yellow fever, chaplets of micrococci or bacteria (Fig. 85), only visible under a very strong magnifying power (more than 1000 diameters). But they are not invariably present, and it is consequently uncertain whether they are the cause of the disease. From its symptoms and lesions, there is reason to think that the parasite or parasites—for there may be several, according to Nägeli's theory—have their seat in the digestive canal. New and sustained researches, carried on in countries where yellow fever prevails, and more methodically conducted, are necessary to elucidate this question.

VII. Typhoid and Typhus Fevers.

These two diseases may be taken together, since in both the digestive canal is the part chiefly affected.

Here crowding, the aggregation of men and the human miasmata resulting from it, play the chief part, admitting, as we have already said, that miasma means microbe. We need not, therefore, deny the influence of predisposing conditions, or what is called receptivity for the disease. These unfavourable conditions are: physical exhaustion, bad food, youth, mental emotion—all which conditions are allied with human miasmata, the result of crowding in barracks, where typhoid fever prevails; in camps, which are more subject to typhus; and in the badly built houses of our large cities.

In few diseases is the influence of anti-hygienic conditions more apparent. Want of air and cleanliness is one of the principal factors of these cruel epidemics. In the confined lodgings of the artisans of large cities, the dead, the sick, and the healthy man may be found sharing the same room and even the same bed; linen impregnated with typhoid excretions may remain for days in the same chamber. The walls and floors of our barracks, too rarely cleansed, disinfected, or whitewashed, harbour myriads of microbes; and the water of adjoining wells likewise contains them in great numbers.

Nor can it be said that hygienic conditions are more carefully observed in the rural habitations of villages and detached farms. The peasant is as ignorant of the laws of health and cleanliness as the artisan; the neglect of the builder, often a mere mason, of the landlord and the tenant, is still more striking in country districts. For this reason epidemics are generally more fatal in the country than in towns; but they are less frequent, of shorter duration, and more easily localized in a village or detached farm, since in this case there is a large supply of oxygen, which is the great destroyer of microbes.

With respect to typhoid fever, one of the most common diseases in this country, the lesions by which it is always characterized show that the microbe producing it is chiefly found in the mucous membrane of the intestines, in Peyer's glands, and in the isolated follicles which cover this membrane, and which are always hypertrophied and softened in typhoid patients. The round red spots which may be observed upon the skin are distinctive marks of the affection of the digestive canal, and it has occurred to Bouchardat that if, as he supposes, these spots contain the same microbe as that of the intestines, it might be cultivated and attenuated into a true vaccine.

The presence of special microbes in typhoid fever was first observed by Recklinghausen in 1871, but the exact description of the typhoid bacillus has been only recently given by Eberth and Klebs.

Eberth has observed this bacillus in the spleen, the lymphatic glands, and the intestines, making use of special staining processes. It appears in the form of short rods with rounded extremities, in the tubular glands and round the bottom of these glands, which cover the mucous membrane of the intestine. They are numerous when the ulceration of Peyer's glands begins; afterwards they become fewer, and are succeeded by other microbes. From the position of the bacteria in a section of the mucous membrane, it may be seen that they penetrate through its surface, and fasten on the ulcerated and mortified tissue (Cornil).

Blood taken from living patients often displays bacilli amid the red corpuscles (Fig. 86). The spleen, which is always hypertrophied, contains the same bacillus, which is also found in the liver, and sometimes in the kidneys and urine.

Many other bacteria appear in the intestines when the disease is approaching its end, but the bacillus in question is the only one found in the blood and internal organs, so that it is really characteristic of the disease.

Gaffky, a German micrographist, and a pupil of Koch, has succeeded in the artificial culture of this microbe, taking it from the spleen of persons who died of typhoid fever. It is actively developed on gelatine and potatoes, becomes very lively and produces endo-

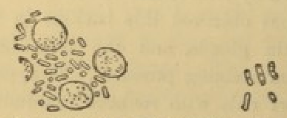


Fig. 86.—Bacilli of typhoid fever (× 1500 diam.): three red corpuscles may be observed in the same preparation.

genous spores at a temperature of 38°. But the inoculation of animals with the disease has hitherto been unsuccessful, at least so as to reproduce in them an affection of the intestines, really resembling that of Peyer's glands in man.

The horse is the only animal affected by a similar disease, which has also been called typhoid fever. In 1881, the horses of the Paris Omnibus Company were decimated by an epidemic of this nature. But the lesion of Peyer's glands cannot be compared with that which occurs in the same glands in man, and no special microbe has yet been discovered.

The presence of the bacillus of typhoid fever in the air or in water has not yet been ascertained. Neither is anything known about the microbe which may be assumed to be the cause of typhus fever.

VIII. The Cholera Microbe.

This terrible disease has its origin in Asia, where its ravages are as great as those of yellow fever in America. It is endemic or permanent in the Ganges delta, whence it generally spreads every year over India. It was not known in Europe until the beginning of the century; but since that time we have had six successive visitations, and it seems destined to replace the plague or black death of the Middle Ages, a disease which appears to be now confined to some few localities of the East.*

In 1817, there was a violent outbreak of cholera at Jessore, India. Thence it spread to the Malay Islands, and to Bourbon (1819); to China and Persia (1821); to Russia in Europe, and especially to St. Petersburg and Moscow (1830). In the following year it overran Poland, Germany, and England, and first appeared in Paris on January 6, 1832; here it raged until the end of September.

* See in the *Annuaire de thérapeutique*, 1885, Bouchardat's account of cholera epidemics in Paris, together with remarks on the nature, the parasite, the hygiene, and the treatment of cholera.

In 1849, the cholera pursued the same route. Coming overland from India through Russia, it appeared in Paris on March 17, and lasted until October.

In 1853, cholera, again coming by this route, was less fatal in Paris, although it lasted for a longer time —from November, 1853, to December, 1854.

The three last epidemics, 1865, 1873, and 1884, differ from the foregoing in not having taken the continental route; they came by the Mediterranean Sea. Brought from India to Egypt by the Mecca pilgrims, the epidemic of 1865 entered France by way of Marseilles, ravaged Provence during the summer of 1865, and was carried to Paris towards the end of September by a woman who came from Marseilles. It was less fatal than the preceding epidemics, and so also was that of 1873.

The epidemic of 1884 took the same route. First localized in Alexandria (1883), it attacked Naples, Marseilles, and Toulon in the summer of 1884, and overran all Provence; thence it was transferred to Nantes, to several towns in the north-west of France, and to Paris, where it was comparatively mild. Finally, it entered Spain at Barcelona towards the end of the year, and ravaged the whole peninsula through the summer of 1885. In August, it also reappeared in Marseilles and Toulon, and this could not be ascribed to a fresh importation from Spain or the East.

The essentially epidemic and contagious progress of this disease clearly indicates the presence of a microbe, of which the chosen seat is the intestines, whence it passes with the patient's fæces, and constitutes the contagious element in places affected by the epidemic.

The first precise micrographic researches made on this subject were those of the French and German commissions sent to Alexandria in 1883. Koch, member of the German sanitary commission, was the first to describe the microbe which it has been decided to consider as the producing agent of cholera. He gave it the name of comma bacillus (*Bacillus komma*), on account of its form.

In order to see these bacilli in any number, a case of malignant cholera must be observed. For this reason, an unsuccessful search for this parasite has often been made, since it cannot be distinguished from the numerous other parasites found with it in the intestines of cholera patients on the second or third day. A small fragment of the *rice-water* evacuation of cholera should be placed on a glass slide and stained with methyl violet or methylene blue; the superfluous liquid must be drained off, and the preparation may then be examined under a magnifying power of from 1200 to 1500 diameters, making use of an immersion lens, on which light is thrown by an achromatic condenser.

The comma bacilli then present the appearance shown in Fig. 87, and, in spite of the colouring matter, are full of motion and activity, which they retain for some time. They are arched in form, and, roughly speaking, resemble a comma. Their length is 1½ micro-millimetres to 2½ micro-millimetres, and their width is 0·6 to 0·7 micro-millimetre. They are often arranged in chains or chaplets, so as to appear like the letter S, or several S's, placed end, to end as we see in Fig. 87. These latter are the most characteristic. Compared

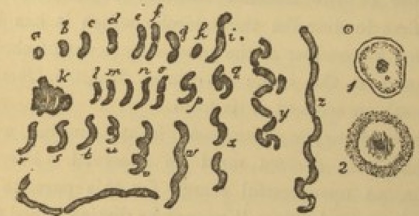


Fig. 87.—Cholera microbe, or *Bacillus komma* (Koch): *a–z*, the different forms which it presents in its growth and division into cells (greatly magnified); 1, 2, cultures of bacillus, under a simple lens.

with the microbe of tuberculosis, that of cholera is shorter and thicker. Its spiral shape has led to the belief that it is an intermediate form between the genera *Bacillus* and *Spirillum*.

Comma-shaped microbes may be found in most stagnant and running water, but they are in general much larger, and none of them present the characteristic dimensions of *Bacillus komma*.

This bacillus is found in the riziform grains of choleraic evacuations, which are, as we know, formed by the desquamation of the mucous membrane of the intestines. The membrane is, in fact, literally flayed from one end to another, and, in consequence of its congestion, the walls of the intestines are of a bright rose colour. The riziform grains consist of small tufts of epithelial cells, conglomerated together, and they contain numerous bacilli.

They are also found in the glands of the intestine into which they penetrate, owing to the desquamation of the epithelium. They have not as yet been found in the kidneys, the urine, or the blood.

Cultures of this microbe on gelatine or gelose are very successful. Koch has observed that it readily multiplies in damp linen, or in milk, broth, eggs, moistened bread, potatoes, etc. The temperature most favourable to it is from 30° to 40°, and even at 20° it still multiplies on gelatine. Below 16° it grows very slowly, but does not perish. Cold does not kill it: at 10° below zero it is still alive, and capable of resuming all its activity when replaced in favourable conditions. This microbe is aërobic, and soon dies when deprived of air.

Water can serve as its vehicle, but does not supply sufficient nutriment, so that it soon disappears. This, however, is not the case with stagnant water containing organic matter. When the level of subterranean waters sinks, the surface water becomes more charged with all kinds of refuse, and the multiplication of germs becomes more easy. Bacilli cultivated in distilled water die within twelve hours, while they can live for a week in drinking-water. (Cornil.)

The influence of the level of the subterranean waters on the progress of cholera epidemics was pointed out in Germany by Pettenkofer long before there was any serious idea of regarding a microbe as the cause.

During his recent travels in India, Koch met with the comma bacillus in the stagnant waters of that country.

For a long while the attempt failed to reproduce Asiatic cholera in animals by injections of comma bacilli, and thus to prove the parasitic nature of the disease. The animals in countries attacked by cholera appear to enjoy immunity in this respect. Nicati and Rietsch at Marseilles were, however, successful in producing cholera by the direct injection of choleraic liquid into the duodenum of guinea-pigs, dogs, etc. Almost all these animals died at the end of two or three days, and the inflamed intestines contained a number of comma bacilli, much more vigorous than those of the injection.

Bochefontaine, of Paris, swallowed pills which contained choleraic evacuations. He felt unwell for some days, but no serious consequences ensued. It is probable that in this case the acidity of the gastric juice attenuated, or partially destroyed the bacilli. We shall see that acids are, in fact, adverse to the development of the microbe. Bochefontaine also injected the choleraic virus under the skin of his arm, but the operation was only followed by an œdematous redness, localized round the puncture, and the constitutional symptoms were not so marked as those produced by taking the same virus into the digestive canal.

Ferran's Attempts at Inoculation.—This leads us to mention the attempts at inoculation made by Ferran on a large scale in Spain, under the name of anti-cholera vaccinations.

In 1884, Ferran, a Tortosa physician, was sent by the municipality of Barcelona to study the infectious agent of cholera at Toulon. His preceding studies in micrography pointed him out for this mission. He returned from Toulon, provided with cultures of the comma bacillus, and devoted himself to the study of its life-history. The facts reported by him differ very much from those previously observed, and cannot be accepted without further investigation.

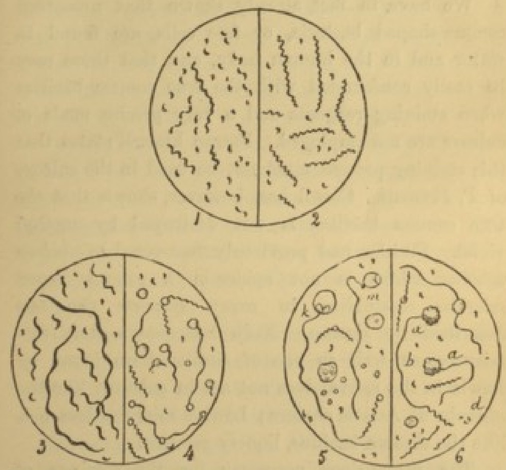
According to Ferran, the cholera microbe presents a polymorphism which has escaped notice in Koch's investigations, and those of the other micrographists who have observed and cultivated it. When transferred to a sterilized alkaline infusion, the comma bacillus increases in length, forms sinuous filaments, then swells at one extremity until it attains to the volume of a red blood-corpuscle, thus constituting an oogonium filled with protoplasm. A transparent envelope (*periplasma*) then encloses the oogonium, which thus becomes an oosphere. Close to this, on the original filament, a small swelling appears, which Ferran regards as the pollinidium, or antheridium, which is intended to fertilize the oosphere and transform it into an oospore.

When the rupture of the oospore occurs, the granules contained in it float in the liquid. Those which have been fertilized grow until they are as large as the original oogonium, and constitute mulberry-shaped bodies, so called on account of the numerous round projections or micrococci which cause the surface to resemble that fruit.

A very slender filament may soon be seen to issue from one of the points of this mulberry-shaped body, a filament which grows longer, and sometimes two of them appear at once. These filaments become sinuous, twist in spirals, form spirilla, and are then segmented so as to form by fission Koch's comma bacilli, which are the starting-point of the culture, and of this cycle of evolution (Figs. 88, 89, 90).

Hence it would appear that the cholera microbe must belong to a much higher group than that of bacteria, to which it has been hitherto assigned. This mode of reproduction would show that it is not an alga, but a fungus of the group of *Peronosporeæ*, and it is, in fact, termed by Ferran *P. Barcinonæ* while his friends prefer to call it *P. Ferrani*, after its discoverer.

Ferran regards this peronospora as the infectious agent of cholera. Yet it seems extraordinary that such a remarkable polymorphism should have escaped the observation of Koch and of the numerous micro-



Figs. 88, 89, 90.—Evolution of cholera microbe (*Peronospora Ferrani*: Ferran): 1. Cholera microbe (*Bacillus komma*), discovered by Koch. 2. Spiral form of bacillus, transferred from gelatine to an infusion. 3. Degeneration of spiral form after a series of successive cultures. 4. Cholera microbe (*Peronospora Ferrani*): development of oogonium on the spirilla and straight filaments. 5. The oogonium is filled with granules which centre in a point *k*, and it is then converted into an oosphere; *m*, pollinidium on fertilizing organ. 6. The oosphere is converted into mulberry-shaped and comma-shaped bodies.

graphists who have made various cultures of the comma bacillus. It is difficult not to suppose that some negligence or error has vitiated Ferran's researches, and the first idea which will occur to any unprejudiced micrographist, is that *P. Ferrani* is not really Koch's comma bacillus, and consequently not the cholera microbe.*

We have, in fact, already shown that numerous comma-shaped bacteria, or free cells, are found in water and in the human body, and that these may be easily confounded with the true comma bacillus when staining reagents and a very precise mode of culture are not employed. Ferran himself states that this staining process must not be used in the culture of *P. Ferrani*. Cornil has, however, shown that the true comma bacillus is not destroyed by methyl violet. Finkler had previously discovered in *cholera nostras*, which is not epidemic, a comma-shaped microbe resembling in many respects the one described by Ferran. Koch has shown that this microbe, as well as one of similar form found by Lewis in the saliva, does not act in cultures like the microbe of Asiatic cholera; Lewis's microbe does not, like the cholera bacillus, liquefy gelatine.

The precautions necessary for the sowings of culture liquids are so great that we may be permitted to doubt whether Ferran has always guarded against error. Brouardel's report shows, after a visit to

* Our criticism on the description and illustrations of Laveran's marsh-fever microbe might be applied, word for word, to Ferran's description and illustrations of the cholera microbe, which we have reproduced above.

Ferran's laboratory, that the instruments and methods in use there were primitive and insufficient.

Until these facts have been confirmed by other observers, it seems prudent to regard *P. Ferrani* and *B. komma* as two absolutely distinct microbes. It does not follow that the culture liquids employed by Ferran did not contain the latter, but it is probable that it also contained, and in larger numbers, a second microbe (?), which is *Peronospora Ferrani*.

It may also be observed, the injection of Ferran's culture liquid into the intestines of guinea-pigs produced no effect, while subcutaneous injections soon killed these animals and distinctly affected men. This is precisely the opposite effect to that observed by Nicati and Rietsch at Marseilles, and by Bochefontaine in Paris.

This is a crucial difference, since it shows that the two microbes are not identical, and all our knowledge of cholera tends to show that its microbe has a special action on the intestines.*

However this may be, Ferran carried on his culture experiments in the endeavour to obtain an attenuated microbe which might serve for preventive inoculations. He believes that he has succeeded, and

* The experiments made by Gibier and Van Ermengen in August, 1885, confirm this opinion. After inoculating a certain number of guinea-pigs, according to Ferran's hypodermic method, with a virulent culture liquid, and giving them time to recover, the same liquid was injected into the stomach of these animals, and they all died with the symptoms and lesions of cholera.

after inoculating himself, he performed the same operation on several of his friends; then on thousands of people in different towns of the province of Barcelona, and throughout Spain.

His inoculation consists in introducing, by means of the small syringe used for hypodermic injection, about a cubic centimetre of the vaccinal liquid, the nature of which is kept secret by its author. There is always a certain discomfort after the operation, but it disappears at the end of a few hours. Ferran himself states that one inoculation will not suffice to ward off the contagion. A second, third, and even more, are necessary for the attainment of this object, but the discomfort caused by the operation always becomes less.

Up to this time the results obtained by the process during the recent epidemic in Spain are not accurately known, since Ferran has been unable to produce the official statistics which are necessary to confirm his assertions.

We are, therefore, entitled to reserve our judgment, both as to the value claimed for this vaccination, and as to the true nature of the microbe cultivated by Ferran, and considered by him to be the infecting agent of cholera. If, again, we recur to the facts established by Bochefontaine, it may be asked whether subcutaneous injection is the true mode of inoculation applicable to this disease, and if the process adopted by Bochefontaine, of introducing the attenuated microbe into the stomach by means of pills or a liquid, would not be more rational.

Mode of Propagation and Persistence of Cholera.—The upper part of the delta of the Ganges seems to be the original home of cholera and its microbe. Below this region, the stagnant water on each side of the river, infected with every species of ordure, renders the maritime base of the delta wholly uninhabitable. But even in its upper part the land is nearly covered by water. In order to build a house, the earth is heaped up to raise the level of the soil, and the house stands on the embankment, surrounded by water. A high temperature is necessary to enable the bacillus to live in water, and it is probable that it will never become acclimatized in our colder climate. The drainage which has been carried on round Calcutta has already rendered epidemics less serious.

The disease is always propagated by man. In India, Arabia, and Egypt, its diffusion is chiefly owing to pilgrimages. In Bengal the pilgrims all bathe together in sacred pools, often only a few square metres in size, and receiving some thousands of men in the course of the day, streaming with sweat and exhausted by long journeys and insufficient food, and under such conditions cholera is often developed. From India it passes to Arabia by means of the Mussulman pilgrims, whose caravans block the narrow streets of Mecca every year, and thence it is transported to Egypt. Finally, it is carried from Alexandria to Marseilles and other Mediterranean ports by vessels which have served for the transport of pilgrims, by men, their linen, and other garments.

It is consequently by the human body and its clothing, or by the water which carries away human fæces or has served for the washing of soiled linen, that the infecting microbes are carried. The air, as it has long been known, need not be taken into account. As early as 1832, it was observed that the wind did not affect the epidemic, which seemed rather to advance like a man travelling by short stages.

Duclaux's recent researches show that the sun and air attenuate and soon destroy the microbes, and that only dead germs are borne on the air and wind. "In order to retain their virulence unimpaired, the microbes must travel in packages of clothing, in bales of merchandise, or in the close, moist hold of a vessel. In a word, of all agents of sanitation, the sun is at once the most universal, the most economical, and the most active to which the guardians of public and private hygiene can have recourse" (Duclaux).

Koch has declared that acids in general are the greatest hindrance to the development of the cholera bacillus. In this way, the acid of the gastric juice is the best safeguard, and many cases of contagion may be explained by the fact that the large quantity of water imbibed has diluted the gastric juice to excess, or else that the source of contagion has rapidly passed through the empty stomach, and has carried a liquid containing dangerous microbes straight into the intestines. Indigestion, and catarrh of the stomach and intestines, of which diarrhœa is a symptom, constitute predisposing causes of the disease.

Among other substances unfavourable to the development of the microbe, and thus constituting a preventive of cholera up to a certain stage, we may mention calcium sulphate, which acts by producing sulphuretted hydrogen gas, also carbolic acid, salicylic acid, thymol, alcohol, acetic acid or vinegar, and mustard oil, which, like the other volatile substances already mentioned, constitutes an excellent antiseptic in an epidemic of cholera.

We shall speak in another chapter of the purity of drinking-water, which is of great importance, and of the improved filters invented to eliminate the microbes which are not arrested by ordinary filters.

IX. The Exanthemata: Scarlatina, Small-pox, Measles, Vaccinia.

Microbes are found in the eruptions characteristic of all these diseases. They are generally micrococci, isolated or in chaplets.

Measles.—Babès, in 1880, was the first to describe the micrococci which he observed in this disease, and especially in the pneumonia by which it is often complicated. The blood of the eruption, the catarrhal secretion of the nose, etc., contain small round bodies, isolated or in pairs (in the form of the figure 8), or more rarely in short chaplets. When there is decided pneumonia, the pulmonary alvéoli likewise contain isolated bacteria, in the form of an 8, in chaplets, and even in zoogloea, or massed together. Babès has not yet cultivated nor tried to inoculate this microbe.

More recently, in January, 1883, Le Bel observed, in the urine of persons attacked by measles, the appearance of slightly curved rods (*bacillus*) capable of very slow movements. Their length varies considerably, and the spores appear in a swelling which occurs at about a third of the length of each rod. This microbe appears for a few days at the beginning of the fever, and disappears with the fever, to return afresh at the moment when peeling begins. We know that these are the two epochs of contagion. The microbe is found in this scurf, and may be obtained by scraping the skin with a knife. Le Bel succeeded in cultivating it in sterilized urine. In serious cases of measles, the microbe remains upon the skin and in the urine for weeks, and even months. It is probable that Babès's micrococcus and Le Bel's bacillus are only two forms of the same microbe.

Scarlatina.—Pohl has found, in the desquamating epidermic cells of this disease, and on the soft palate, micrococci of somewhat smaller size than those of measles. A bacterium in the form of an 8 has also been found in the urine of scarlet-fever patients.

Stickler believes that he has discovered a vaccine for scarlatina, by passing its virus through the horse or the cow. When these animals are inoculated with the blood of a man suffering from the disease, an eruption accompanied by desquamation occurs three days after inoculation. A man inoculated with this desquamation displayed a rash resembling that of scarlatina, and when the same man was afterwards inoculated with human scarlatina, he did not take the disease.

Small-pox and Vaccinia.—We find in small-pox pustules micrococci, either isolated or united, which may be seen on a section of the skin if they are coloured with methyl violet. The same microbe may be observed on the pustules of the mucous membrane of the larynx, in the liver, the kidneys, and the blood of the vena portæ. The attempt to cultivate it has hitherto failed.

The micrococcus found in small-pox pustules does not differ in its form from that of cow-pox in cows, which constitutes, as we know, the original source of human vaccine. It is not yet certain that the microbes of small-pox and vaccinia are identical, but from the resemblance of the pustules and of the micrococci contained in them, it is most probable that this is the case, and this would explain why vaccine is efficacious as a preventive of small-pox.

It may be useful to retrace here the curious history of vaccine, since it is directly interesting to us all.

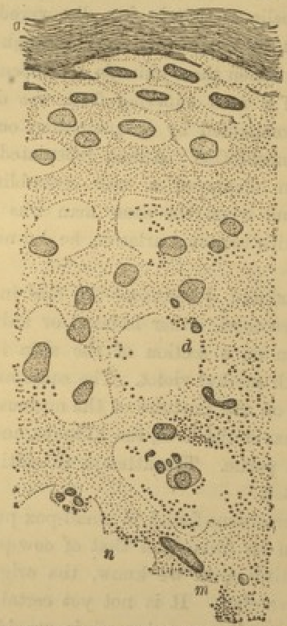


Fig. 91.—Section of skin covering a small-pox pustule. *a*, horny layer of the epidermis; *d*, adenoid tissue; *m*, *m*, micrococci stained with methyl violet (× 850 diam.).

Before vaccine was discovered, inoculation with small-pox was practised as a preventive measure.

This inoculation was known to the Arabs and Chinese as early as the tenth century, but it was decried by physicians, and only practised by women. In India it was practised by the Brahmins, and a public crier announced that he had small-pox virus to sell.

In 1717, Lady Mary Wortley Montague, wife of the English Ambassador in Constantinople, chanced to see the operation performed by an old Thessalian woman, who always accompanied the puncture with practices of witchcraft and superstitious usages. She asserted that the Virgin herself had appeared to reveal the secret to her, and boasted of having performed inoculation in more than 40,000 cases. Lady Mary was so much impressed by the results obtained that she had her son inoculated, and it is said that the old Thessalian handled her rusty needle so unskilfully that Maitland, the physician attached to the embassy, was obliged to finish the operation. On her return to England, Lady Mary made the success of the experiment generally known. George I. authorized the inoculation of six prisoners in Newgate, and then of six orphans. The operation was performed by Maitland and crowned with success, and he was then allowed to inoculate members of the royal family, and more than 200 other persons.

The practice was, however, condemned by the clergy, who considered it to be immoral and anti-religious, as being opposed to the divine rights and will. Some failures, such as the death of Lord Sunderland's son, awakened alarm, and caused inoculation to be discredited.

Notwithstanding this, it was introduced into France in 1723 by De La Costa, and accepted by Chirac, Helvetius, and by other physicians of the day. Although opposed by the majority, and officially condemned by a decree of the Sorbonne in 1753, as "unlawful and contrary to the law of God"—a decree officially confirmed by the faculty of medicine in 1763—inoculation continued to be practised up to the time when vaccination was substituted for it.

Vaccination appears to have been practised in Asia in earlier times. However this may be, it was known in the south of France that farm servants who had been affected by cow-pox were secured against small-pox. These pustules generally occur on the udder, and the milkers were inoculated with the vaccine matter, through some accidental scratch on their hands. Rabault, a Frenchman, communicated this fact in 1798 to Pew, an English physician and a friend of Jenner. To Jenner we must assign the merit of understanding the importance of this fact, and deducing from it one of the most admirable discoveries of modern medicine, the preventive method which continually tends to become more general, and to be extended to other diseases, especially since Pasteur's late researches into vaccination for anthrax and for fowl-cholera.

Pasteur has also shown t the microbes are the active principle of the vaccine virus. The liquid need only be deprived by filtration of its micrococci in order to become inert, and consequently unfit for use in vaccination.

X. The Microbes of Croup and Whooping-cough.

The parasitic nature of croup and diphtheria, which had long been suspected, was only shown in 1881 by the researches of two American physicians, Wood and Formad. In the spring of that year a very serious epidemic of croup occurred at Ludington, a small town on the borders of Lake Michigan. Here the principal industry is derived from the neighbouring forests, the trees of which are sawn into planks in the numerous saw-pits, and thus employ almost the whole working population. The town stands on a height, with the exception of one quarter of it, which is built on very low, marshy ground, partly filled up with saw-dust. Here the soil is so wet that when a small hole is dug, it fills with water immediately, and cellars are almost unknown. It was in this quarter that the epidemic was so severe; almost all the children were attacked by it, and a third of them had already died.

Formad went to Ludington to study the epidemic and collect materials for experiments. In all these cases of croup, the blood was full of micrococci belonging to *Micrococcus diphthericus,* some detached, others united in the form of *zoogloea*, that is agglutinated in small masses; others, again, in the colourless corpuscles of the blood. All the organs, and especially the kidneys, were likewise filled with them.

With the materials gathered at Ludington, Wood and Formad made some experiments in cultures, and were able to inoculate rabbits with croup. These inoculations were made subcutaneously, in the muscles and trachea, and were followed by the production of false membranes, and the animals died with all the symptoms of diphtheria. The blood was full of micrococci. An examination of living animals showed that the micrococcus first attacked the colourless corpuscles, within which their vibratile motion could be observed. The corpuscle changed in appearance, the granules disappeared, and it became so full of micrococci that they could no longer move: they grew until they caused the rupture of the corpuscle, and then escaped in the form of an irregular mass, which constitutes the *zoogloea*. Corpuscles filled with micrococci were found in the false membrane; in the small vessels, which they dilate and completely obliterate; and even in the marrow of the bones.

Cultures made in flasks afforded important results. A comparison of the sowings made with micrococci collected at Ludington with those found in the ordinary diphtheritic angina, which is common at Philadelphia, showed a great difference in the vitality and virulent properties of microbes derived from these two sources. The former multiplied rapidly and energetically, succeeding each other up to the tenth generation, while those from Philadelphia only went to the fourth or fifth generation, and those taken from the tongue did not go beyond the third. It must be observed that the diphtheritic angina of Philadelphia is much less fatal than croup, and the first attempts at inoculation made by Formad and Wood produced doubtful results, precisely because they were made with the microbe of diphtheritic angina, which is an attenuated form of the microbe of croup. The organism is the same, but it is modified by the medium in which it is developed, and the vitality of artificial cultures is in direct proportion to the malignity of the disease from which the germs for sowings are derived.

The following theory may be deduced from these facts, which will explain all cases of diphtheria:—A child contracts a simple catarrhal angina, or laryngitis; the micrococci, which up to this time remained inert in the mouth, begin to grow and multiply under the influence of the inflammatory products which favour their development; the plant which has been dormant becomes widely diffused. There are many degrees between croup with malignant complications and the mildest form of diphtheritic angina, as all practical physicians know. More or less numerous germs of micrococci float in the air, or—which appeared to be the case at Ludington—are conveyed in drinking-water, and they may encounter more or less favourable conditions. If they settle on a child's tender throat, predisposed for their reception by slight inflammation, they develop there with frightful rapidity, and produce croup, and then diphtheria, which is soon fatal. Nägeli calculates that their number may be doubled within twenty minutes. The plant, of which the activity is increased by its culture in the person of one patient, may be expelled with the breath so as to infect another individual. And just as there are different degrees of activity in the plant, so the spores may be more or less contagious, and those of malignant diphtheria are more to be feared than those of the ordinary diphtheritic angina.

When we consider the remedies to be employed against the ravages of this cruel disease, it should first be observed that the only effect of the operation of tracheotomy, which is successful in barely a third of the cases, is to admit air into the child's lungs. Its first curative effect, therefore, consists in saving the child from the asphyxia by which it is threatened, and in giving time to apply remedies, but another explanation is necessary when this operation alone is enough to effect a cure. Pasteur has shown that prolonged contact with the air produces a real attenuation of virulent microbes. Wood and Formad have established similar facts, for when the false membranes of croup procured at Ludington had been exposed to the air for several weeks, until they were completely desiccated, they became perfectly inert, notwithstanding their former virulence. They were, however, not dead, since they were still capable of reproduction, but only up to the third or fourth generation. It must, therefore, be admitted that the free access of air given by tracheotomy, may attenuate the virulence of the micrococcus of croup.

Too much cannot be said against the misuse of emetics, which is, unfortunately, very common, since they are readily administered by parents without medical advice. A regular emetic of which the action is much more violent than that of ipecacuanha should never be given. The micrococci are only found in the most superficial layers of the false membranes, and when these are removed, an irritated and bleeding mucous membrane remains, which had been previously protected by the false membrane from immediate contact with the microbes: these now pass without difficulty into the blood. Thus the ground may be said to be prepared and rendered more favourable for the multiplication of the micrococci, which are sown there afresh, and are reproduced with frightful rapidity.

The most effectual remedy has been prescribed by Dr. Fontaine of Bar-sur-Seine. It consists in administering sulphurous drugs, in the form of sulphate of calcium, so as to produce in the stomach a slow disengagement of sulphuretted hydrogen gas, which checks the development of microbes, or attenuates their virulence. It need scarcely be said that this treatment must begin at once, before the micrococci have penetrated into the blood. At the same time a gargle of lemon-juice or citric acid should be used, which shrivels up the false membranes without forcibly detaching them. The action of this acid is explained by the fact that, for the most part, microbes only thrive in an alkaline medium. By this treatment Fontaine has been able to save nine-tenths of his patients, while all other modes of treatment have only succeeded in a third of the cases, and the proportion is often much smaller.

The first researches made in Europe on the microbe of diphtheria date from 1873, at which time Klebs gave an exact description of it under the name *Microsporon diphtericum*. In most cases he observed two forms: micrococci and rods or bacilli. Struck by the great difference in intensity which the disease presents in different epidemics, he states in his later works that there are two kinds of diphtheria, due to the predominance of one or other of these two forms, one of which he terms *microsporine*, and the other *bacillary*. The former may be observed in the east of Europe, and especially in Hungary; while the latter is more common in Switzerland and the west, including France. The first is chiefly found upon the tonsils, and is less serious; while the bacillary form soon attacks the larynx and trachea, and produces blood-poisoning, which is rapidly fatal. The bacilli which are, like those of tuberculosis, very minute, remain on the surface of the false membranes, more rarely within them, and on the surface of the inflamed mucous membrane.

Löffler undertook experiments in culture and inoculation which confirm Klebs' opinion. He succeeded in isolating and cultivating separately the *Microsporon*, or micrococcus, and the bacillus, which makes it probable that these are two distinct species. The chaplets of micrococci, cultivated separately and used to inoculate animals, do not produce diphtheria; the bacilli, on the other hand, cause the formation of false membranes, but do not exactly reproduce the diphtheria of the human subject.

Cornil and Babès have likewise studied these two forms of microbes. They have ascertained that the bacilli are more generally found in the false membranes of the skin, and the micrococci in those of the throat and larynx. But in almost all cases they have found bacilli, zoogloea, and chaplets of micrococci associated together in the false membranes, even in those of the skin, and bacilli in those of the throat.

Cornil and Mégnin have studied the spontaneous diphtheria of poultry and domestic quadrupeds. The anatomical lesions and the form of the microbes approximate to those of human diphtheria, and cases of contagion between the calf and man have been observed. Yet direct inoculation has failed, so that it is still impossible to affirm the identity of the two diseases.

We do not think that the dual nature of human diphtheria, indicated by the researches of Klebs and Löffler, is yet established. The symptoms, and still more the histological lesions of this disease, are in favour of its unity, and it may be owing to other causes that the disease is more or less severe.

The well-known polymorphism of microbes leads us to think that the bacilli represent the adult form, and the micrococci, or *Microsporon*, the early form of a single species, which is in all cases the cause of diphtheria and of its several manifestations—croup, diphtheria, etc. Further researches are necessary to decide this question.

Whooping-cough and Influenza.—Burger has lately discovered rods in the form of an 8 in the sputum of whooping-cough; they are found in great numbers in the white scum, and are even visible to the naked eye, and, like many other bacteria, they can be stained by methyl violet. To this microbe whooping-cough and its relapses are due, and it is always present. It has not yet been cultivated.

Influenza resembles whooping-cough in the course it takes, and is probably also caused by microbes. Letzerich has found micrococci in the blood, to which he ascribes this disease, but his researches must be repeated with greater care.

Certain facts observed in medical practice have led to the surmise that whooping-cough may be regarded as an attenuated form of croup, just as vaccinia is an attenuated form of small-pox. The same treatment applies to both diseases. When the patient is kept in the purifying chamber of a gas manufactory, where there is a constant disengagement of acid vapours, sulphuretted hydrogen, hydro-carbons, coal tar, benzine, carbolic acid, etc., the microbes embedded in the throat and lungs are attenuated. Sulphate of calcium is a successful remedy in whooping-cough as well as in croup.

Children who have had whooping-cough, or who are passing through the disease, rarely contract croup even when it is epidemic, although catarrh, inflammation of the bronchial tubes, ulceration of the mouth, and general debility, are all predisposing causes of croup. The question therefore arises whether whooping-cough does not act as a sort of preventive vaccination which may serve as a protection against croup. Further researches and observations should be made in this direction, if that which we now indicate can be established as a fact.

XI. The Microbes of Phthisis and of Leprosy.

These two microbes are so similar in form that it is necessary to have recourse to chemical reagents and to staining processes in order to distinguish them clearly. Both assume the form of an 8, or of slender, elongated rods, so minute that it is not surprising that the bacillus should have so long eluded the observation of the physiologists who have studied the tubercle of phthisis under the microscope. The form of both microbes assigns them to the genus *bacillus*.

The experiments of Villemin, begun ten or twelve years ago, first showed the parasitic nature of tuberculosis, or pulmonary phthisis. Villemin inoculated rabbits with tubercular matter, showing that the disease was essentially contagious. More recently Toussaint and Koch have cultivated the microbe in a closed vessel, and have inoculated animals with the produce of the culture; all these animals died with symptoms of tuberculosis.

The still more recent researches of Cornil, as he stated in May, 1883, before the Academy of Medicine, have confirmed the parasitic nature of this terrible disease. The microbe has been found in the giant cells of the tubercle and in the sputum of consumptive patients; it has been found in the colourless corpuscles of the blood, by which it is conveyed into all parts of the system, and it is also found in all the organs in which a tubercle can be developed.

The bacillus of tuberculosis is somewhat smaller than that of leprosy. Each bacillus is from three to four micro-millimetres in length. They are generally found associated in the form of chains or chaplets—at any rate, this is the case in the sputum, as we see in Fig. 91A. Koch has cultivated them in gelatinized blood-serum. Their growth is very slow.

Now that this is known, it is easy to explain the facts of direct contagion which are so frequent among people living together, and especially from a husband to a wife, or conversely. Since the breath of a consumptive patient is always charged with germs of the microbe, which abound in the cavities in which

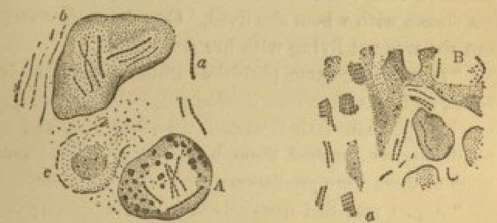


Fig. 91A.—Bacilli in the sputum of a consumptive patient: A, bacilli, either isolated (a) or in the epithelial (b) and pigmented (c) cells of the lung; B, numerous bacilli, massed together in the sputum. Stained by Ehrlich's process with methyl violet (much enlarged).

the sputum is formed, it could not possibly be otherwise. The following statements of facts are taken from Debove's clinical lectures at the Hospital de la Pitié.

"Jean, a tuberculous patient, was married to Antoinette, a young woman with no previous tendency to tuberculosis. Jean died, and his wife became phthisical. She was remarried to Louis, who had likewise no phthisical taint; Louis and Antoinette both died of phthisis. The niece of the latter, equally without phthisical taint, contracted the disease in nursing her aunt, then married, and her husband was in his turn attacked by phthisis. All these people resided in a place in which it was easy to verify the absence of hereditary taint."

Here are other observations of the same nature:—

"A young woman without hereditary taint nursed a phthisical patient and contracted phthisis. She returned home, and communicated the disease to the six sisters with whom she lived. One sister survived, but she was not living with her family.

"A soldier became phthisical while with his regiment, and was therefore discharged, and returned to his family. His father, mother, two brothers, and a neighbour who nursed them, became phthisical. Yet none of them were predisposed by hereditary taint.

"A girl returned from school in consumption; on her death her room and clothes passed to her sister, who died of the same disease. A third sister died under like conditions. As their parents still survive, it is clear that the disease was not due to heredity."

This does not imply that heredity plays no part in the transmission of the disease, for the contrary is proved; yet such transmission often occurs after the child is born, and sometimes the nurse by whom it is suckled may be the source of contagion.

In the case of children brought up by hand, the infection may come from cow's milk which has not been boiled. Cows are often attacked by tuberculosis, and numerous bacilli have been found in the teats and milk of these animals. This indicates the necessity of boiling the milk used for food, especially in the case of children, at any rate when the source is unknown.*

Phthisis is, as we know, a slow disease, probably because the microbe is anaërobic, and lives within the cellular tissue, not in the blood, which it merely traverses. The slow progress of the disease explains the cases of spontaneous cure effected by the expulsion of the microbe in the sputum, or by the tubercles passing into a cretaceous condition, which causes the destruction of the bacteria encysted in them. Hence also the fact that all the causes which weaken the constitution, bad food, overwork, inflammatory diseases, pregnancy, etc., hasten the end of consumptive persons. Those who are attacked by the disease may, if rich enough to live in the South, and to follow with care the hygienic prescriptions of the physician, often attain an advanced age, in spite of the lesions which remain latent in the organism, provided also they commit no imprudence in the matter of diet.

It is therefore important to maintain the strength of consumptive patients by tonics, by a nourishing diet, and by an hygiene as strictly protective as possible. The good effects of creosote, of sulphur waters, etc., are due, as in diphtheria, to the attenuation of the

* This precaution is equally efficacious to ward off typhoid fever. In several epidemics of this disease, and especially in England, inquiry has shown that milk was the vehicle of contagion, either from the water with which it was adulterated, or from that which was used to wash the vessels in which it was placed.

virulent properties of the microbe. Hansen considers that alkalis, not acids, are the best antiseptics in this disease.

Tubercular leprosy, termed elephantiasis by the ancients, is caused by tubercles seated in the skin, and containing a bacillus greatly resembling that of phthisis, but larger (Fig. 92). This microbe is anaë-

Fig. 92.—Bacilli of leprosy, encysted in the subcutaneous connective tissue of the skin (much enlarged).

robic, and can only live in the dermic cells, in which it is encysted. Hence the treatment which experience, preceding the theory, showed to be the most efficacious: instead of keeping the ulcers covered, they should be exposed to the air and sun, often washed, and kept as clean as possible. This disease, which is essentially contagious, is very rare in Europe, but common in Egypt and throughout Asia.

XII. The Microbe of Pneumonia.

One of the most important micrographic discoveries of late years is that a microbe is always present in inflammation of the lungs, or pneumonia. This disease was long considered, and is still considered by the majority of doctors, to be altogether independent of any parasitic infection. It is such a matter of tradition, both among patients and their doctors, to ascribe this disease to accidental causes, and especially to a sudden chill, that the parasitic doctrine of pneumonia at once encountered a lively

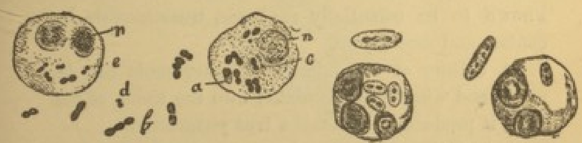


Fig. 93.—Micrococci in sputum of pneumonia: *b*, *d*, free, or encysted in the lymphatic cells *a*, *c*; *n*, nuclei of cells (much enlarged).

opposition. It is, however, now impossible to deny the important part taken by microbes in the transmission of this disease.

The microbe of pneumonia was discovered by Friedlander and Talamon in 1882. It consists of micrococci, often associated in an 8 or in short chains (Fig. 93), and found in the sputum and lungs of pneumonic patients, either detached or encysted in the lymphatic cells.

Under a strong magnifying power, this micrococcus is seen to be shaped like a lance-head, and short rods, terminating in a cone, are found with it. It is probable that the micrococcus is the early form of the microbe, which becomes a bacillus in the adult form (Cornil).

The presence of a microbe in pneumonia explains many facts which had remained obscure in this disease, especially the epidemics in a room or house, when several persons living together are successively attacked by pneumonia. It likewise explains the resemblance, which has long been indicated by their common name, between the pneumonia of man and the contagious pneumonia of cattle, which is well known to be essentially epidemic, transmissible by contact and inoculation.

A culture of the microbe of pneumonia can be made, and when it is inoculated into the tissue of the lung, it produces in animals a true pneumonia.

XIII. Some other Diseases caused by Microbes.

We shall only say a few words about several other diseases, admitted to be contagious, and in which the presence of a special microbe has been ascertained.

In the pus-corpuscles of gonorrhœa, very minute and mobile micrococci may be observed, often associated in pairs, in fours, or in a small mass, but rarely in chaplets (Fig. 94).

The same micrococcus, or, at any rate, a microbe which cannot be distinguished from it, is often found in the purulent ophthalmia of new-born infants. It is difficult to admit, even when we make allowance for the great susceptibility of an infant's eyes at the moment of birth, that such ophthalmia is always of gonorrhœal origin. However this may be, the micrococci of purulent ophthalmia resemble those of gonorrhœa, and the same treatment is applicable. The solution of nitrate of silver in a diluted form, generally employed in maternity hospitals, as a pre-

Fig. 94.—Cells of gonorrhœal pus 24 hours after its discharge. Within may be seen several forms of fission of their nuclei, and micrococci moving in the protoplasm (× 600 diam.).

ventive treatment of infant ophthalmia, has considerably reduced the intensity of this disease.

The red, malodorous sweat of the armpits is due to the presence of a microbe, which is found free in the sweat, or massed in the form of a zoogloea, and adherent to the hair of the skin. The red colour is not due to iron, for no trace of this metal is revealed by analysis; it approximates in its nature to that of *Micrococcus prodigiosus*. It may be cultivated in white of egg at a temperature of 37°, in which it retains its characteristic colour.

In a sweating foot, of which the smell is so offensive, Rosenbach found a short, thick rod, which is at once aërobic and anaërobic, is rapidly developed, and retains its offensive smell when cultivated (Fig. 95).

In the gangrene of long bones, the same observer

Fig. 95.—Bacillus of feet-sweat.

Fig. 96.—Saprogenic bacillus of osseous gangrene.

has found a similar bacillus, which, like the foregoing one, produces by inoculation a local affection, more or less strongly marked (Fig. 96).

Warts.—We know that a wart is self-sown, and appears to contain a contagious principle. This is Tomasi Crudeli's *Bacterium porri*, and is minute and in the form of an 8.

Among the diseases due to microbes we must include mumps, epidemic goitre, epithelial xerosis of the eye, polypus of the nasal canal, of which the concretions are formed of *Streptothrix Forsteri*, etc.

XIV. The Microbe of Erysipelas.

Erysipelas belongs both to internal and external pathology. It is sometimes manifested as a special primary disease, characterized by the inflammation of the skin, and sometimes as a secondary complication of wounds, sores, and surgical operations. In any case, the course taken by the disease and its contagious nature enables us to assume the presence of a microbe. Martin, Volkmann, and Hüter found bacteria in the patches of skin; and Hayem found them in the pus of meningitis, which followed erysipelas of the face. Lukomski was able to inoculate rabbits with the disease, which may also be communicated by vaccine lymph, taken from a child suffering from erysipelas. Fehleisen has cultivated the microbe in a pure state,

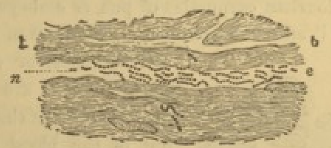


Fig. 97.—Section of the skin in erysipelas: the interfascicular space (e) is full of microbes (m) in 8's or chains; t, connective tissue (× 600 diam.).

and has inoculated man with it, always reproducing erysipelas with its characteristics and typical course. Antiseptics, such as carbolic acid and analogous substances, employed either as outward applications or as subcutaneous injections, have been successful in many instances in arresting the development of the disease.

Erysipelas serves as the transition to those diseases within the domain of surgery, and which are generally due to sores, wounds, and operations.

XV. Microbes of Pus; Pyæmia and Septicæmia.

Sores and surgical operations are often followed by a general poisoning of the blood and of the whole system—a severe affection which is rapidly fatal, and characterized by the presence of pus-corpuscles in considerable numbers in the blood and in the principal organs. Together with these pus-corpuscles there is always a special microbe, termed *Micrococcus septicus*, which, like that of diphtheria, may either appear free or in the form of chaplets (*vibrio*), or in the interior of the colourless corpuscles of pus, or embryonic cells, of which it effects the rupture in the form of *zoogloea*.

Fig. 98.—Pus-corpuscles of puerperal peritonitis, full of micrococci in chains (× 800 diam.).

This microbe, or others of allied species, are the immediate cause of that poisoning of the blood which is termed pyæmia, septicæmia, traumatic fever, puerperal fever, post-mortem wounds, etc. The germs of *Micrococcus septicus* are introduced into the blood, and multiply there, through the exposed surface of a wound, or sometimes by means of the instrument which caused it (Fig. 98).

When the instrument causing the wound is charged with microbes, it is not necessary that the wound should be gaping: there is in this case a true inoculation. Such is the case in a post-mortem wound. The experiments of Tédenat, of Lyons, show that when decomposition has not begun in the corpses of healthy persons, who have died by violence, the autopsy presents no danger; but this is not the case when death is due to an infectious disease, pyæmia, erysipelas, etc. On the other hand, the puncture will have no evil results if the bleeding is profuse, or if the microbes and their germs have been removed by immediate suction. Some hours after death, all corpses contain microbes, which have penetrated into the blood owing to the softening of the tissues, and which either come from the external air or from the digestive canal.

The enormous number of pus-corpuscles which appear in a very short time in the blood was for a long while a problem for physicians. It is now known that these corpuscles have their source not only in the wound, but also in all parts of the vascular system, and especially in the capillaries, according to Schiff's theory. The microbian theory may easily be made to agree with the latter, and Sternberg was the first to suggest that it appears to be the function of the colourless corpuscles to take possession of the bacteria introduced into the blood, and to destroy them. We know, in fact, that the colourless corpuscles do take possession of all foreign particles, such as micrococci and bacteria, introduced into the blood, and in some sense encyst them in their protoplasm. When these bacteria multiply in the blood, they must necessarily have an irritating effect on the walls of the blood-capillaries and this appears in the swelling of the cells and their return to the spherical form; in a word, they are transformed into embryonic or migratory cells (according to Cohnheim's theory). These do not differ, or only differ slightly, from the colourless corpuscles of the blood, and are pus-corpuscles. This new theory is in accordance with the facts daily presented to us in the treatment of surgical diseases.

XVI. Microbes of some other Diseases, resulting from Wounds.

Whitlow and Agnail.—These two complaints are produced by pricking the finger with some instrument charged with microbes. Chains of bacteria or micrococci are always found in the collection of pus or serous discharge.

Boil and Carbuncle.—The pus from a boil contains micrococci, which Pasteur first observed, and which he has cultivated in an infusion of yeast and in chicken-broth.

It was found by Rosenbach in osteomyelitis, and was termed by him *Staphylococcus pyogenus aureus* (Fig. 99).

Carbuncle only differs from a boil in its larger size, and contains the same microbe. It is well known that it is readily and spontaneously self-inoculated, and that boils and carbuncles rarely occur singly in the same individual. Diabetic patients are very subject to this affection, yet the microbe does not admit of culture in sugared water.

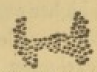


Fig. 99.—Boil microbe (*Staphylococcus pyogenus aureus*; Rosenbach).

Phlegmon.—This is the name given to the suppuration of the subcutaneous cellular tissue, caused by contusions, wounds, and medical injections of morphia or any other substance. Microbes are always found associated in 8's or in long sinuous chains (Fig. 100). In all these cases there has been some communication with the outer air, for wounds which are really subcutaneous—fractures, for example—even when accompanied by abundant hæmorrhage, heal without suppuration, and microbes are not present.

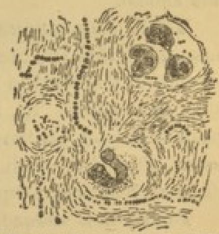


Fig. 100.—Pus of phlegmon, containing chains of micrococci (× 1000 diam.).

XVII. Mode of Action of Microbes in Disease. Ptomaïnes.

The question how microbes act in disease has long been doubtful, but the progress of science tends to clear away obscurity.

The first idea was that microbes introduced into the blood or tissue of an animal acted like parasites of a higher organism—intestinal worms, for instance—by deriving their nourishment from their medium, and developing at its expense. It is evident that this must be the case, and that in anthrax, or splenic fever, for example, the bacilli which swarm in the blood abstract from the red corpuscles the oxygen they require, and thus produce asphyxia and the death of the animal.

Yet it often happens, even in anthrax, that death is so rapid, that the bacilli have not yet had time to develop in the blood in numbers sufficient to produce such fatal effects. So, again, in cholera, the comma bacillus has not yet been found in the blood, and yet cases of sudden death are not uncommon in this disease. Some other explanation is therefore required.

Panum first showed, from the study of the products of putrefaction, that a poisonous substance, resembling snake-venom and vegetable alkaloids, is developed as the ultimate product of the putrid fermentation of organic matter. Twelve milligrammes of this substance kill a dog, while neither ammonia nor the acids which are first formed in this fermentation can produce septicæmia. Bergemann and Schmiedeberg have termed this poisonous substance *septine*.

Panum's researches have been recently resumed by Selmi and Gautier, who have extracted from corpses and putrefying organic matter a certain number of poisonous substances greatly resembling vegetable alkaloids, and termed by them *ptomaïnes*.

The action of ptomaïnes may be compared to that of strychnine. Injected into the blood, even after the removal of every living microbe, the ptomaïnes produce fever, rigors, vomiting, diarrhœa, spasms, torpor, collapse, and finally death. It is probable that in some cases of poisoning by tainted meat or fish their poisonous properties are due to the presence of ptomaïnes.

But in all cases these ptomaïnes are shown to be the product of putrid fermentation, which is always effected in dead bodies by special microbes. Here the ptomaïnes are due to the work of the microbes of putrefaction, and are made by them, just as alcohol and the carbonic acid of alcoholic fermentation are made by yeast, at the expense of the sugared liquid in which they live and multiply.

Direct experiments show that when septine, from which every microbe has been removed, is injected into the human subject, it produces feverish disturbance, but only causes death when introduced in considerable quantities. If, on the other hand, there is in the same individual a large suppurating wound, exposed to the air instead of being covered by an air-tight dressing, a purulent infection (septicæmia) will almost certainly ensue, since the microbes introduced by means of this wound will find in it a favourable soil (pus and putrefying organic matter); they will multiply in immense numbers, and manufacture of these materials a great quantity of septic poison, at the expense of the organism in which they are developed.

It is now admitted that the chief action of pathogenic microbes, or, at any rate, of the most dangerous among them, consists in the ptomaïnes which they secrete within the body. This explains why death by cholera is so rapid and even sudden, when the comma bacillus is still only found in the intestines. Although this micro-organism has not been absorbed by the intestinal mucous membrane and carried into the blood, the poisonous alkaloid, or ptomaïne, which it secretes is certainly present, and to this the nervous symptoms, such as cramp, etc., which characterize this disease, may probably be ascribed.

Pouchet has extracted from the fæces of choleraic patients, a special alkaloid of the nature of ptomaïne; and quite recently, in August, 1885, he has found traces of the same alkaloid in infusions of pure culture of Koch's comma bacillus.*

In conclusion, at the present stage of our knowledge, it may be admitted that the action of pathogenic microbes on the system is complex, and may be analyzed as follows:—(1) The action of a living

* This affords the germ of the idea of a new process for preparing lymph, which has perhaps already been put in practice. A Spanish physician states that the secret process employed by Ferran simply consists in filtering his culture infusion by means of the Chamberland filter, and using this liquid for inoculation, since it contains the ptomaïne of cholera without its bacillus (?).

parasite, which is nourished and multiplies at the expense of the fluids and gases of the system; (2) the formation by this parasite of a poisonous substance (ptomaïne), of which the elements are derived from the organism, and it acts as a poison on this organism.

CHAPTER VI.

MEANS OF DEFENCE AGAINST MICROBES.

I. Antiseptic Treatment of Wounds: Guérin's Protective Dressing; Lister's Dressing.

The first and most brilliant application of the theory of microbes to human therapeutics has been made in the treatment of wounds.

Since it is admitted that the danger of a wound or of a surgical operation is chiefly due to the contact of the wound with the external air, which is laden with germs, or with the dressing which may contain microbes, all the surgeon's efforts should be directed to preventing such contact. This may be accomplished by several processes, now generally employed by surgeons, and these may be regarded as the noblest achievement of modern surgery.

In Guérin's protective dressing, this skilful surgeon has made a practical use of Tyndal's and Pasteur's researches into the nature of air-germs. We have already said that air filtered through a sufficiently thick layer of cotton wool becomes free from germs. Guérin covers that part of the body in which the wound is situated with several layers of cotton wool, carefully applied and confined by a cotton bandage. This dressing permits the access of air to a certain extent, but the air is filtered through the cotton wool, which arrests all microbes; and this is proved by removing the dressing after the lapse of several days, when the wound will be found to be in a satisfactory state, and in process of healing. A certain amount of pus is produced, but much less than in the old-fashioned lint dressing, and this pus is not putrefied, since the germs which are the agents of putrefaction have been excluded.

The English surgeon, Lister, has arrived at the same result by a more complicated process, which has, however, been generally adopted in France. His process is based on the use of carbolic acid as an antiseptic or destructive agent of microbes and germs. Whenever an operation is to be performed, the instruments, the surgeon's hands, those of his assistants, and all the materials used for dressing, must be steeped in a sufficiently dilute solution of carbolic acid; throughout the operation the wound must be surrounded with a spray of the same solution, playing over the hands of the surgeon and over all he touches. The same solution and the same precautions are applicable to the treatment of all wounds, whatever be their origin, and should be renewed whenever the wound is dressed.

We cannot describe Lister's dressing in detail, but will only mention—(1) that the skin surrounding the region of the operation, the surgeon's hands, and the instruments are washed with a carbolic solution of two to three per cent.; (2) the spray contains one per cent. of carbolic acid; (3) the ligature of the arteries is done with carbolized catgut, which is eventually dissolved in the wound; (4) the drainage-tube usually arranged for the outflow of the discharge is likewise carbolized; (5) so also are the eight folds of gauze, which is used instead of linen dressings; (6) a protective, consisting of green oiled silk, steeped in carbolic acid and varnished like court-plaister, is interposed to prevent the irritating effect of the gauze on the wound; (7) an impermeable mackintosh, laid between the seventh and eighth folds of gauze, prevents the penetration of fluids.

The admirable results obtained by Lister's method are the strongest confirmation of the truth of the theory of microbes. Since its introduction into medical practice, mortality among the wounded and among the surgical patients has considerably diminished, and operations formerly considered impracticable have been undertaken and successfully carried out.

Carbolic acid is not the only antiseptic which affords excellent results by destroying, or at all events by attenuating, the virulence of microbes and their germs. Alcohol, which has been long in use, boracic acid, salicylic acid, thymol (essence of thyme), and eucalyptol (the essence extracted from *Eucalyptus globulus*), and many other substances, have been employed both internally and externally with this object, and most of them take a more or less important place in the therapeutics of those diseases caused by microbes.

II. Hygiene of Drinking-Water: Water free from Microbes; Chamberland Filter.

The researches carried on by Miquel for some years at the Observatory of Montsouris, at the Pantheon, and in other parts of Paris, teach us that living bacteria are more rare in the atmosphere than had been generally supposed. We have already said that air is the great purifier of microbes, which it destroys by desiccation. Even in the infection of wounds, it is probable that the liquids and linen formerly employed for dressings transported the microbes in greater number than the air, however charged it might be with these organisms in the neighbourhood of a hospital.

In the water which supplies large towns, whether furnished from wells or streams, a large number of microbes are, however, found in a state of perfect vitality. This is quite natural, since we know that these plants cannot exist without moisture, and they find in such water the organic matter which nourishes them. The rivers receive them by the sewers which discharge into them, the wells by infiltration of the soil, and thus in times of epidemic, the microbes of typhoid fever and of cholera are always to be found in running or stagnant waters, which therefore become the vehicle of infectious diseases.

Well-water, owing to its stagnant nature, and to the infiltration to which it is liable from cesspools which are often leaky, is more dangerous than running water. About two years ago, an epidemic of typhoid fever, which occurred in one quarter of Angers, was stopped by introducing a supply of water from the Loire; up to that time well-water had been exclusively in use.

Well-water in Bread-making.—In many places well-water is still too often used for making bread instead of running water. There are probably many reasons for this preference. Bakers, without assigning any reason for the fact, assert that well-water causes the bread to rise better; and moreover, in towns, such as Angers, where there is a water company, river-water costs money, while well-water may be had for nothing. About 50 per cent. of water is used in making bread, which explains the preference shown by bakers for well-water, and also the importance ascribed by hygienists to the purity of the water used in bread-making.

In fact, direct experiments, made with a maximum registering thermometer enclosed in the dough, shows that the internal temperature of the loaf, that of the crumb, rarely rises to 100°. We know that this temperature does not suffice to destroy most microbes, still less their germs, for which a temperature of from 115° to 160° is necessary.

In 1884, Bouvet, a chemist, and Préaubert, a professor at the Lycée, were commissioned by the municipality of Angers to make a microscopic examination of numerous specimens of well-water used by bakers in their trade in different parts of the town. The examination of deposits, either obtained spontaneously by allowing the water to stand for twenty-four hours, or by testing the water with osmic acid, in accordance with Certes's process, almost invariably revealed the presence not only of the ova of ascarides, but of numerous microbes — some of them harmless, like *Bacterium termo*; others doubtful, on account of their forming chains like the micrococcus (two species of different form), and resembling *Micrococcus diphthericus.* Now, croup may be regarded as endemic at Angers. In four wells out of the twenty-five examined these microbes were found in great numbers. It must be noted that micrococci are not found in strongly aërated water, but only in that of which the organic deposit is abundant.

Well-water must, therefore, be generally condemned, both for drinking purposes and for the making of bread. Spring-water, and still more river-water, as it is now supplied in towns by a system of pipes, is not free from organic matter, nor from microbes, although they are less abundant than in well-water. Purification is therefore necessary.

With this object, it is recommended, especially in times of epidemic, to boil the water, so as to destroy the microbes contained in it. But this process expels the gases, and reduces the proportion of salts in solution, thus rendering the water heavy and indigestible. It has, therefore, been suggested that only weak mineral waters should be drunk, such as that of Saint Galmier, which, if taken at the source and immediately placed in hermetically sealed bottles, contains very few microbes. But this process is costly, so that only rich people can avail themselves of it. The most practicable mode of purifying table-water and rendering it wholesome is by the use of filters.

Ordinary Filters. Chamberland's Microbe Filter. —Every one is acquainted with the common filter, made with crushed sandstone, charcoal, etc., which should be found in all households and kitchens. This generally suffices to free water from organic matter, and especially from the ova of ascarides (intestinal worms), which, when introduced into the system, develop and cause inconvenience to so many children, and even to grown persons. It is impossible to insist too strongly on the fact that the presence of ascarides in the intestines is always due to the use of unfiltered water, and this should enforce the general use of filters, which is often neglected even by those who cannot be deterred by the relatively moderate cost of an instrument which it is almost impossible to wear out. An ordinary filter, however, can arrest a very small proportion of microbes, which are much more minute than the ova of ascarides.

A filter has, therefore, been devised, so perfect as to allow the passage of no solid matter in suspension, not even the most minute organisms contained in drinking-water. This result is effected by the filter invented by Chamberland in Pasteur's laboratory. The filter is formed (Fig. 101) of a vessel of biscuit-ware, A, shaped like a candle (whence its name of *bougie Chamberland*); this is fastened to the lower part of the metallic receiver D, which receives under pressure the water coming from the cock E. This vessel consequently filters the water from without to within, and it flows through the orifice B, perfectly free from solid particles, as it appears from a micrographic examination.

Fitted to the distributing water-taps of many houses in Paris, and especially in lycées, the Chamberland filter acts under the normal pressure of the water-conduit, and, by a new modification of the inventor, can even act without such pressure. For this purpose he arranges his filters in a battery, from eight to ten or more, in a cylindrical receiver, closed in its upper part. This receiver is connected by a caoutchouc tube with the vessel which contains water

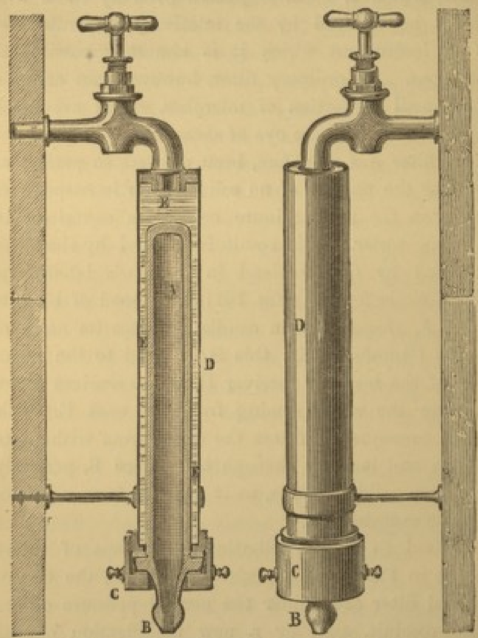


Fig. 101.—Section and elevation of Chamberland's filter.

for filtering. When the vessel is placed two or three metres above the filter, from fifteen to twenty litres of perfectly pure water may be obtained in the course of an hour. Under the pressure of the taps of the Paris water-supply, the jet of the filtered water is as strong as that of the pipes used for watering our gardens; in fact, it gives out four or five litres a minute under the pressure of two or three atmospheres.

Preservation of Alimentary Substances. Appert's Protective Process, etc.—We have already said that organic substances may be preserved unchanged for an indefinite time, as long as they are protected from the microbes and germs in the air. This was shown by Pasteur's exhaustive experiments. He took urine and blood, and transferred them directly from the animal organs into glass flasks which had been previously sterilized or deprived of all germs. These flasks were hermetically closed and kept for forty-five days. When opened at the end of that time, it was ascertained that the smell and appearance of the liquids were unchanged, that no putrid gas had been developed, and even that some of the oxygen in the flasks had not been absorbed.

Most of the processes in use, even before this experiment, for the preservation of food substances, are only the practical application of this principle: the exclusion of microbes and germs.

Appert's process, now so generally used to preserve meat and vegetables, consists in enclosing the substances to be preserved in tins, which are hermetically closed, and heated to a temperature of 110°, so as to ensure the destruction of all germs. A very small aperture is left at the top of the case for the escape of steam and air, which is closed with a drop of solder before the ebullition of the liquid within is completely over.

The envelopment of meat in its own fat, its preservation in sugar, wax, etc., are analogous protective processes, always employed at a high temperature.

When meat is smoked, the aromatic principles of carbolic acid, creosote, etc., contained in the smoke, destroy the ferments and prevent the subsequent development of air-germs. It is, therefore, a true antiseptic, analogous to the salts used to preserve meat or fish by pickling. Meat may also be preserved by desiccation, when it is cut in thin strips and exposed to the sun and air. This constitutes the jerked beef of South America.

Excellent results are now obtained by drying meat at from 35° to 55° in a stove through which a current of dry air is passed. The powdered meats to be obtained from chemists, which are of great use in nourishing the sick and convalescent, are prepared by an improvement on this process. They are absolutely free from smell, and will keep as long as they are protected from damp. Vegetables cooked by steam, and then compressed and dried, may be kept for several years.

Refrigeration by ice has been used to preserve meat. But when congelation has occurred in the fluids contained in the muscular tissue, putrefaction sets in, and rapidly increases, as soon as the temperature rises a few degrees above freezing-point. The meat also acquires an unpleasantly sweet taste. It will be remembered that the first cargo of frozen American meat which was brought to Paris had contracted an unpleasant taste and was very soon tainted. When meat, game, or fish is kept in ice, the congelation of the fluids contained in their tissues must therefore be avoided.

Many antiseptics, vinegar, alcohol, glycerine, etc., may likewise be used to preserve meat and other alimentary substances.

Antiseptics and Disinfectants.—We will discuss the substances which are thus designated, especially from the hygienic point of view, and as a preventive treatment of contagious diseases, indicating the action of these substances on microbes.

Antiseptics have been studied by Jalan de La Croix with reference to their action on microbes in general. His experiments were performed on culture liquids made of the juice of cooked meat, into which he introduced an equal number of drops of the same broth, which contained fully developed bacteria. He next ascertained the dose, in milligrammes, of an antiseptic substance which would suffice either to arrest their multiplication or to destroy the microbes, and consequently to sterilize the liquid.

He analysed in this way twenty substances considered to be antiseptic, or commonly used as such. He has published a table in which these substances are classified in their order of activity, and it includes among others the following antiseptics, which we cite in the order assigned to them :—

Corrosive sublimate (mercuric chloride)	No. 1
Chloride of lime at 98°...	No. 3
Sulphurous acid	No. 4
Essence of mustard	No. 9
Thymol	No. 13
Salicylic acid	No. 14
Carbolic acid	No. 16
Boracic acid	No. 18
Alcohol	No. 19
Essence of eucalyptus	No. 20

The three last substances are incapable of sterilizing culture broths.

This table shows that carbolic acid, which is now so much in use, does not destroy microbes so efficiently as salicylic acid, permanganate of potassium, thymol, benzoic acid, bromides, and iodine. In this estimate, however, we must take into account how far the use of each antiseptic is practicable.

Thus, corrosive sublimate, which these experiments show to be the best antiseptic, can be used as an external lotion, but it cannot be given internally in doses sufficient to produce the desired effect. Eighty milligrammes are required to sterilize a litre of broth, and forty to arrest the development of bacteria. Twenty milligrammes will not effect this result, and this latter dose is a maximum which it is almost impossible to exceed in man in the course of twenty-four hours without poisoning him.

Sulphurous acid is very effectual when employed in fumigations, but it does not penetrate to the interior of the tissues, and only acts on the microbes on their surface. It does not destroy their spores.

Iodine has great effect in this respect. Davaine has ascertained that seven milligrammes of iodine suffice to destroy the bacteria of anthrax in a litre of liquid. Instead of a hot iron, tincture of iodine might, therefore, be used to cauterize the bites of poisonous flies, carbuncles, and the pustule of anthrax.

Koch states that a solution of five per cent. of carbolic acid is required to destroy the spores of anthrax in twenty-four hours; but the bacilli themselves are destroyed by a solution of one per cent. A solution of 0·02 per cent. iodine, or 0·07 per cent. of bromine prevents the development of bacilli.

Chloride of zinc and sulphate of iron, which have been recommended as disinfectants, are very inferior to chloride of lime, which takes the third place in the list, the second being occupied by chlorine.

Alcohol arrests the development of bacteria and their spores, but does not destroy the latter, even at the end of a month, as it is stated by Claude Bernard.

Babès regards essence of mustard as an excellent preservative from cholera. If a drop of this essence is put at the bottom of a bell-glass which covers a culture of comma bacilli, it arrests their development and destroys them within forty-eight hours.

When cholera is epidemic, it has been suggested that rum or cognac should be taken, to which salicylic acid is added, in the proportion of 25 grammes to the litre. A *petit verre*, or three teaspoonsful, of this mixture may be taken between meals in coffee, tea, or grog.

Redard has been recently occupied with the disinfection of the railway-waggons used for the transport of cattle. He regards most of the substances employed, including sulphurous acid, as insufficient. The only effectual process is by steam, at a temperature of 110°, which may be easily procured at the railway stations.

As we have already said, the oxygen contained in air is an excellent antiseptic, and the attempt has been made to employ it; but the experiments of Bert and Regnard show that bacteria are only destroyed by oxygen at a high pressure. As for oxygenated water, it has not yet afforded the results which were expected from it.

Finally, each species of microbe appears to be more or less sensitive to the action of different therapeutic agents. Thus the effect of mercurial salts on the microbe of syphilis was known before the existence of the microbe itself was known; that of the salts of quinine and arsenic on the microbes of intermittent fever, etc.

We must, in conclusion, rely much more upon measures of hygiene than on antiseptics to ward off the attacks of the microbes which are factors of disease. Even in Lister's dressing, it is probable that the hermetic closing of the wound has, as it is shown by Guérin's process, much more effect than carbolic acid, which is shown by direct experiments to be a feeble and generally an insufficient antiseptic.

We have still to speak of the preventive vaccinations and inoculations on which medicine relies more than on antiseptics; but this subject will be better discussed in the following chapter, when we have spoken of the processes of culture by which the liquids destined for these inoculations are prepared.

CHAPTER VII.

LABORATORY RESEARCH, AND CULTURE OF MICROBES.

THE processes employed in laboratories for the study and culture of pathogenic microbes are now very complicated, and they have attained a remarkable degree of perfection. In such an elementary work as this we can only give a general idea of these different processes, and for details we must refer our readers to the valuable work by Cornil and Babès, *Les Bactéries,* in which the *technique* of laboratories devoted to the histology of microbes is described with great accuracy and clearness.

Microscopes.—The best instruments for the research and study of microbes are those of Zeiss, Jena, and Vérick, Paris. Immersion lenses, either for use in water or in other homogeneous liquids, are indispensable for the high magnifying power which is necessary in order to see most bacteria distinctly. Condensers, especially those of Abbé, made by Zeiss, are no less useful in order to concentrate the luminous rays on that point of the preparation which is to be specially examined, and to place the bacteria in relief after they have been stained by the process we are about to mention.

A preparation ought first to be examined under a low magnifying power (from 50 to 100 diameters), so as to study the topography of the object, and ascertain the points at which the colonies of microbes may be sought amid the tissues of a section, or of the matters in suspension in the liquid.

We should then go on to a higher magnifying power (for example, to from 500 to 700 diameters), making use of the simple light of the mirror; and we should ultimately come to the highest magnifying powers (from 1000 to 1500 diameters), using immersion-lenses and the condenser.

Instruments, Microtome.—The instruments for fine dissection are those commonly used in histology. In addition, needles of glass and platinum are necessary, and thin spatulas of nickel to convey the sections, etc.

The ordinary razor, which serves for hand sections, will not do for the thin, wide sections necessary for the discovery of bacteria. In this case a microtome must be used, an instrument for making thin sections, for which purpose those of Thoma or Vérick are the best. Sometimes the object to be examined is hardened by freezing it with ether spray, since this makes it possible to cut thin sections by hand. This is Jung's process.

Non-staining Liquid Reagents. — Acids, bases, alcohol, oil of aniline, and other essences serve to dehydrate and partially decolourize preparations. Canada balsam is used to mount them; and finally distilled water, absolutely free from microbes, which may be easily obtained by means of the Chamberland filter already described, is used for washing instruments, etc.

Mode of collecting the Liquids to be examined.—In order to collect the liquids to be obtained in the wards of a hospital or elsewhere (blood, urine, sputum, stagnant or sewer water, etc.), pipettes, which may be either straight or with twisted necks, are used, ending in a capillary point closed by heat, and in its upper part by a stopper of fine, sterilized cotton wool. The pipette is heated at a blowpipe flame, in order to destroy the germs. When it is to be used, the point is broken off, and it is plunged into the liquid (discharge from a freshly opened abscess, blister of erysipelas, etc.), and an aspiration is made through the other end. The liquid is unable to rise above the level of the twisted neck; and this is important, especially when the aspiration is made by the mouth. The point is then resealed at the lamp. The shape of these pipettes may be varied according to the requirements, so long as the same precautions are always taken to avoid mistakes.

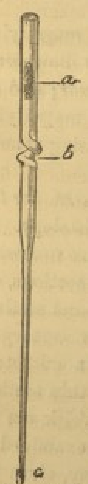


Fig. 102.—Small pipette with twisted neck, corked with cotton wool and sterilized.

Preparations.—Such precautions, and especially the most scrupulous cleanliness, are necessary in making preparations, since air, water, dust, the human hand, and instruments may all introduce foreign microbes. The instruments should be washed in absolute alcohol, and it is still more effectual to heat them to a temperature of from 150° to 200°.

As to the liquids (pus, mucus, etc.), the upper surface should not be taken, but that which is nearest to the tissues, and it should be spread on a thin slide by a platinum wire, which has been heated red hot and then allowed to cool.

When the tissues are to be examined, part of them is detached by a knife which has been heated red hot. It is placed in Jung's freezing microtome, in order to cut sections, after it has been hardened in alcohol, to which bichromate of potassium is sometimes added. The sections are made as large as possible, and are then instantly transferred to a capsule full of alcohol, in which they spontaneously unfold. The glass or platinum needle, and the nickel or platinum spatula, serve to spread out and smooth these sections.

Staining Methods.—Aniline dyes have the property of giving a more vivid colour to the bacteria than to the surrounding tissues, often even without destroying them or altering their movements. This property has been turned to account, and the staining of preparations is now largely practised.

Methyl-violet, or fuchsin, in aqueous solution, serves to stain the living bacteria in a drop of water, under a cover-glass. A small drop of the staining liquid is slowly diffused into the preparation, and gradually tinges the bacteria without giving any sensible colour to the liquid which contains them. When the comma bacillus of cholera is thus treated, it is still capable of motion after the lapse of twenty-four hours, and it will continue to develop if the stage of the microscope is heated to 25°.

In sections which have been hardened or dried in alcohol the bacteria have ceased to live, but they may be stained with the following reagents—Grenacher's borassic carmine, hematoxylin, and tincture of iodine may be respectively employed, according to the species of microbe which is to be stained: Micrococcus, the flagellum of bacteria, *Bacillus amylobacter*, moulds, etc.

Aniline dyes, with an alkaline or acid basis, are very numerous and varied; methyl-violet and gentian in oil of aniline, or in aqueous solution, rosine, saffronine, Bismarck brown, purpurine, etc.

It is often desired to effect a double staining of the section, the tissues, for example, being stained red, and the bacteria violet, or conversely. Picrocarminate of ammonium gives this effect by the following process:—After staining the preparation with methyl-violet, it is dipped for a moment in the iodide solution, and washed in water or weak alcohol; it is then steeped for some minutes in the picrocarminate, of which the colour is made lighter by washing with absolute alcohol and oil of cloves, and the preparation is afterwards mounted in balsam. The nuclei of the cells are then of a carmine red, and the bacteria are violet; the rest of the preparation is of a much paler colour.

Ehrlich's Method.—We mentioned this method when speaking of the bacillus of tuberculosis. It consists in treating the sections or mounted preparation with a solution of methyl-violet in aniline oil, and the colour is afterwards quickly discharged in nitric acid; the bacteria alone remain violet. Fuchsin, methylene blue, coccinine, vesuvine, etc., are also employed in various processes for staining bacteria.

Measurement, Drawings, and Photographs.—Bacteria are measured by comparing them with the divisions of the micro-millimetre slide placed on the stage of the microscope over the preparation. The microbes may be drawn without much difficulty by means of the camera lucida—at least, after a little practice, as their forms are not at all complex. But the results afforded by photography are, as it is plain, very superior. The photographic plate is indeed more sensitive than the eye, and often allows us to see details which had escaped the latter. Koch has given good illustrations of pathogenic bacteria in his book entitled, *Beiträge zur Biologie der Pflanzen*, vol. ii. (1877).

Methods of Microbe Culture.—The development of microbes may be observed by placing the drop of liquid to be examined in Ranvier's moist chamber, consisting of a glass holder, with a circular groove and a flat space in the centre. On the top is a cover-glass,

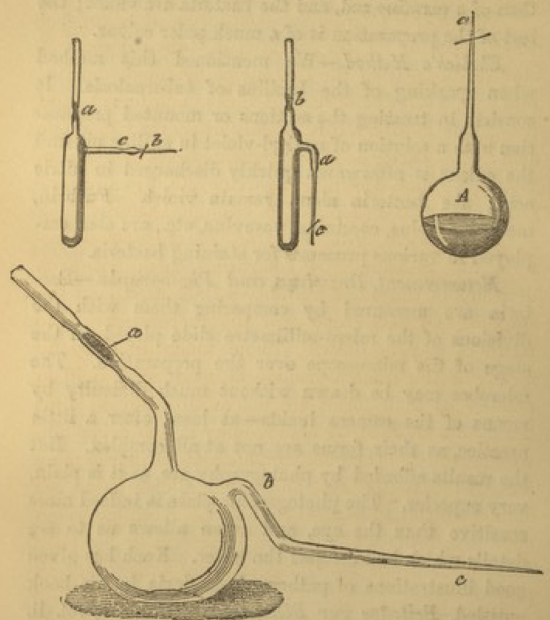


Fig. 103.—Different forms of culture flasks employed by Pasteur (from Duclaux).

which is bordered with paraffin or vaseline, in order to seal it. The groove contains air and a little liquid.

The stage of the microscope is maintained at the requisite temperature.

In order to make cultures in large quantities, other kinds of apparatus are in use. The liquid supposed to contain microbes is introduced into sterilized nutritive liquids by means of a platinum wire, which has been heated red hot and then allowed to cool; its end is

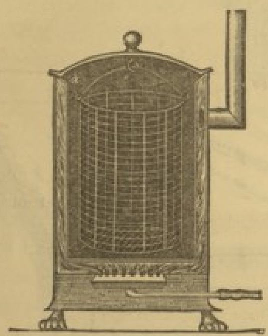


Fig. 104.—Gas stove for the heating and sterilizing of flasks.

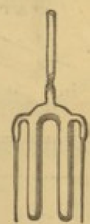


Fig. 105.—Pasteur's culture tubes.

dipped into the liquid, and then instantly transferred to the culture, while it is exposed to the heat of a spirit-lamp. The flask is then sealed with a wad of cotton wool.

The culture liquids employed by Pasteur are the extract of beer-yeast, an infusion of hay, boiled and neutralized urine, and the broth of various kinds of meat. The flasks are all modifications of the form indicated in Fig. 76. These flasks are heated in an iron gas stove (Fig. 104), of which the double case is heated by gasburners, and it contains a basket of iron wire as the receptacle of the flasks, tubes. etc., which

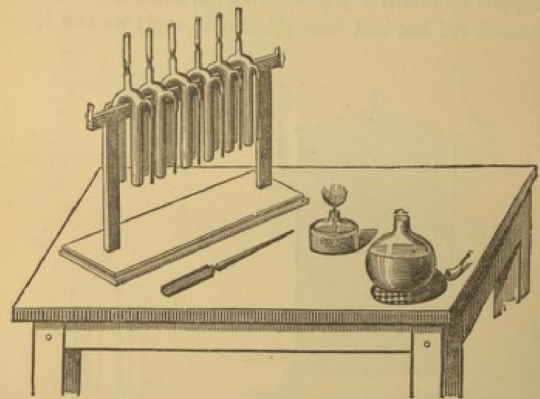


Fig. 106.—Stand, bearing culture tubes.

are to be sterilized. The temperature, regulated by a thermometer, must rise to from 150° to 250°.

The nutritive liquid is boiled in a porcelain crucible in the open air, and is introduced by breaking off the tapered end of the flask; it is then instantly plunged into the broth, and drawn by an aspiration through the opposite tube, after which the tapered end is resealed at the lamp.

The tubes, which have two reservoirs and two tapered ends (Figs. 105, 106), are very numerous in Pasteur's laboratory. They are ranged on a stand in the way shown in the figure.

It is ascertained that the contents of the tubes are really sterilized by leaving them for several days in a stove which is maintained at a temperature of 35°.

In addition to the culture liquids already indicated, many others consist of various solutions of phosphates of lime and potassium, albuminous solutions, etc.

Solid Nutritive Substances.—In order to isolate the different species of bacteria, and to obtain pure cultures, solid substances are now preferred: eggs, slices of potatoes and carrots, but especially gelatine and gelose—which comes from Japan ready for use, and is said to be extracted from a marine alga—and the gelatinized serum of the blood of oxen. All these substances are transparent, so that the cultures can be easily observed in glass tubes. Koch, in his Berlin laboratory, makes almost exclusive use of solid media, which are first sterilized by similar precautions.

In order to obtain pure cultures, all kinds of germs are first allowed to grow; then a very small amount of them is taken from the culture medium, and transferred to the sterilized medium, in which fewer microbes naturally appear. After several repetitions of this transplantation, sufficiently pure cultures may generally be obtained within a short time.

Koch employs a more certain method. He makes his sowings on glass plates, covered with sterilized gelatine and kept at a temperature of 30°, by means of a slender platinum wire which has been made red hot, then allowed to cool, and charged with a very minute particle of matter, which is full of bacteria. The colonies of different microbes isolate themselves, and may be plainly seen on the glass plate with the aid of a magnifier. Their variable size and characters often enable experienced observers to distinguish them by their aspect alone (Fig. 87, 1, 2). The test-tubes, containing sterilized gelatine, are then inoculated with the microbe which it is desired to study (Figs. 82, 105), after taking the usual precautions.

The filters used to sterilize liquids are of Sèvres biscuit-ware heated to 120°, or unglazed pottery. Such is the Chamberland filter already described.

Cultures for Experiments on Animals.—The processes we have just indicated are also necessary in these experiments. Here likewise all the causes of error which would arise from the want of cleanliness, or from the impurity of the culture liquids, must be carefully avoided; and it must also be ascertained that the effect produced on the animal is not due to any other microbe than that of the experiment, nor to any irritating and septic substance. The experiment should be repeated several times by taking some of the blood of the inoculated animal, and making a pure culture, which may be used to reproduce the disease in other animals.

Attenuation of Pathogenic Microbes.—Successive cultures have established, as we have seen, the possibility of attenuating virus, and transforming it into vaccine. The processes employed to attain this object are complex and varied, according to the species of bacterium with which we have to do.

Thus, for fowl-cholera, Pasteur found that cultures dating from fifteen days, or from one, two, eight, and ten months, progressively lost their virulence, and he believes this attenuation to be due to the action of the oxygen of the air. So, again, Koch supposes that the action of the air and the desiccation of the germs produces, after a time, the natural extinction of the disease.

Toussiant and Chauveau attenuate the virus of anthrax, as we have seen, by subjecting it to a temperature of from 42° to 43°. Pasteur and Thuillier have attenuated the virus of swine fever by passing it through the system of a rabbit. Pasteur has also attenuated the virus of rabies, of which the microbe is still unknown, by passing it successively through the systems of a rabbit, monkey, etc.

Finally, the same result may be obtained by adding various antiseptic substances to culture liquids, and thus weakening the virulent action of the microbe.

Vaccination and Inoculation.—The attenuated virus or vaccine thus obtained may be used for inoculation in quantities which experience indicates to be necessary and sufficient, quantities which vary according to circumstances. In order to vaccinate a sheep against anthrax, the animal must be held by its fore feet in a sitting position, so as to present its belly to the operator; the tube of a Pravaz syringe, containing the injection, is then inserted in the base of the groin, which is devoid of wool. In cattle the operation is performed at the root of the tail. It is performed twice—first with a weak vaccine, and, after the lapse of a week, with one which is stronger.

Every one is acquainted with the process of vaccinating the human subject against small-pox, which may be done either with lymph from an infant or from a calf. A lancet or grooved needle is employed, on which there is a drop of lymph, and five or six punctures are made on the arms or thighs.

We must not imagine that vaccination can become an absolute preservative from all diseases. For instance, in erysipelas, pneumonia, and gonorrhœa a first attack is so far from warding off a second attack of the same disease, that it creates a favourable field for relapses. It may, consequently, be assumed *a priori* that vaccination in such cases would do more harm than good (Cornil). It is the same with intermittent fever, tuberculosis, syphilis, etc.; all diseases by which the same individual may be attacked several times, and at varying intervals of time—a clear proof that the first attack has created no immunity against subsequent attacks.

Immunity.—This term is applied to the property which the organism may acquire of being safe from attacks of certain diseases due to microbes, either in consequence of a former attack, or from a condition which doubtless arises from absorbing the pathogenic poison in minute doses, often repeated. Acclimatization frequently constitutes immunity. Thus, in countries where malaria, yellow fever, etc., prevail, the inhabitants are less apt to contract the disease than strangers. Such immunity is not absolute, and may be lost in course of time. This has been ascertained in the case of small-pox, so that it is prudent to be revaccinated every ten or twelve years.

CHAPTER VIII.

POLYMORPHISM OF MICROBES.

MICROBES (bacteria, ferments, and moulds) display, like all the lower types of the animal and vegetable kingdoms, considerable polymorphism. It is necessary, therefore, that we should be on our guard, lest this phenomenon should be the source of errors and confusions very prejudicial to science, either by describing as distinct species different forms of the same species, or by being, on the other hand, led to regard as one and the same species several which are really distinct, and which for want of proper precautions, have been brought together in the same preparation, without the observer being aware of the fact.

We have indicated in the foregoing chapter the scrupulous care which is indispensable in laboratories in order to guard against surprises of this kind. These precautions are not always sufficient, and experience shows that a single act of forgetfulness or distraction on the part of the observer is enough to spoil the result of a long series of researches. Moreover, these precautions often afford only a negative result, since some bacteria which have been reproduced for a long while in the same form in a given medium of culture, suddenly change their form and habits on being transferred to another medium.

In order to give an idea of the difficulties which beset this branch of research, it will be enough to cite the history of lichens, a history well known to all cryptogamous botanists. The structure of these lower plants is at once simple and complex, since we may regard them as formed by the association, or *symbiosis*, as it is technically called, in each lichen of a species of green alga with a species of colourless fungus of the Ascomycetes group.

De Bary and the botanists of his school, Schwendener, Bornet, Reess, Stahl, etc., state that in what is called a lichen the tissues of an alga and those of a fungus are intermingled in such a way as to form the structure which constitutes the lichen. Owing to this close association, a lichen can live like other plants, not as a parasite, like fungi: the green parts of the alga assimilate the carbon contained in the air in the form of carbonic acid, and thus supply nutriment to the fungus, which is consequently regarded as a sort of parasite to the alga. In return, the fungus supplies its mycelium to the lichen, by which the latter is enabled to fasten on the surface of rocks or trees.

This attractive theory was in favour for a considerable time. It is now almost completely abandoned, and recent researches, made with the view of isolating the alga and fungus which were supposed to co-exist in the lichen, tend more and more to show that the lichen is an independent plant, and not merely an association of two plants of distinct families, algæ and fungi.

Errors of the same kind may occur in the study of microbes, which, from their minute size, their unicellular nature, the rapidity of their growth, the variety of their habitat, and the great resemblance of their form, are still more difficult to distinguish than lichens. Of this we will give some examples.

Polymorphism of Leptothrix buccalis. — Robin (1866–1873), after studying the development of *Leptothrix*, stated that this microbe first appears in the form of a micrococcus; then of a moving bacterium, resembling *B. termo*, *B. lineolum*, etc., and finally it forms the long immovable rod (*bacillus*), which constitutes *Leptothrix buccalis*. This mode of evolution, supposed to be usual in the genera *Bacillus* and *Leptothrix*, is probably exact, and, with some reserve as to the specific identity of the different forms observed by Robin, modern micrographists are disposed to accept it. But Robin goes further: he regards the anthrax bacillus as specifically identical with *Leptothrix buccalis*. The recent progress of science no longer permits us to allow this identity. We have seen that there are, at any rate, two species, quite distinct in their action upon men and animals.

Polymorphism of Moulds.—The comparatively early researches of Hallier and others tend to show that the fungi of moulds display considerable polymorphism, so as to completely overthrow the classification of these cryptogams. These researches have been recently resumed by Cocardas, who considers it proved that all the moulds found in saccharine liquids which have been allowed to ferment and in pharmaceutical extracts belong to one and the same species, which is highly polymorphic, and which he terms the Penicillium ferment. Cocardas asserts that he has seen this Penicillium ferment pass through the following successive stages :—Corpuscular (*Micrococcus*), bacteridian (*Bacterium*, *Bacillus*), zooglairian (colonies, or *zoogloea*), submerged hyphæ (*torula*, chaplets, or chains), fructiferous filaments (endogenous spores), the whole constituting the algous phase of the cryptogam which floats on the surface of syrup.

The fungoid phase then begins. The swellings formed on the surface of the liquid by the endogenous spores bud ; these buds become elongated, partitioned, and ramified, constituting the aërial mycelium on which the aërial fructifications are developed, which can only form outside the liquid.

These fructifications, although all issuing from the same mycelium, may present either the form of aspergillus, of mucor, or of penicillium, according to the nature of the spores on the fructiferous hypha. In other words, the characters which have been hitherto considered as proper to the three genera, *Aspergillus*, *Mucor*, and *Penicillium*, themselves types of three very distinct families, are found either simultaneously,

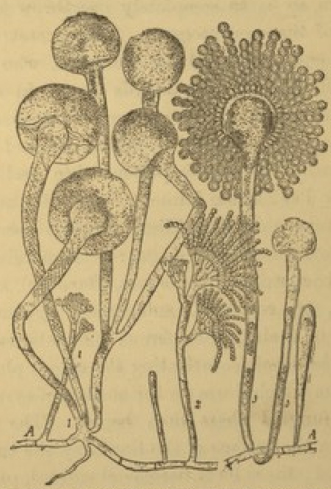


Fig. 107.—The penicillium ferment (Cocardas). Aërial fructification in extract of liquorice: the three forms, *Mucor* (1), *Penicillium* (2), *Aspergillus* (3), borne by a single hypha A (× 225 diam.).

or successively, on the same hypha, and are only varied forms of a highly polymorphic species, the penicillium ferment (Cocardas).

Fig. 107 represents the three forms of fructification, as Cocardas states that he has seen them, united and borne by a single hypha, magnified 225 diameters.

Each form of *Penicillium* belongs to a special change in the syrup. In syrup which has become turbid, the ferment is in the corpuscular or bacteridian stage; when the syrup is ropy, it is in the zooglairian or filamentous stage; when it has turned sour, it is in the stage of aquatic fructification; finally, when the syrup is mouldy, it is in the stage of aërial fructification.

Cocardas states that he has observed this really astonishing polymorphism while making use of the ordinary precautions for averting gross errors. Notwithstanding facts of the same kind, which have been put forward previously, notably by Hallier, but which are frequently contradicted by more accurate research, it may be asked whether this is not merely a phenomenon of confusion, analogous to that which was rightly or wrongly supposed to exist in the case of lichens. Fresh researches, made with greater precision in sterilized liquids, and accompanied by the most scrupulous precautions, are necessary before these facts can be definitively accepted by science.

Polymorphism of Fungi of the Human Skin.—It is more easy to accept, at any rate in part, the polymorphism recently noted by Grawitz in the fungus of *Favus* (ringworm), which we have already described under the name of *Achorion Schoenlenii.*

Grawitz asserts that *Achorion Schoelenii* of ringworm, *Trichophyton tonsurans* of cirinnate herpes, and *Microsporon furfur* of variegated pityriasis, are only different forms of one and the same parasite, of which he has made a successful culture on gelatine, reproducing its successive appearances.

Grawitz, however, goes further than many micrographists will consent to follow him. He asserts that all the fungi of the human skin are only transplanted forms, modified by the medium, of *Oïdium lactis*, the white mould found on milk, bread, paste, potatoes, etc.

So, again, *Oïdium albicans*, the fungus of thrush, is, as we have said, specifically identical with *Saccharomyces mycoderma*, or flowers of wine, a ferment which is developed on the surface of liquids which are acid and contain little sugar. This must not be confounded with *Mycoderma aceti*, a true bacterium, causing the acid fermentation of wine and beer.

Still more recently, in 1883, Malcolm Morris and G. C. Henderson have stated that in an artificial culture of peptonized gelatine at the temperature of from 15° to 20°, spores of *Trichophyton tonsurans* were developed, forming ramified hyphæ which were afterwards covered with fructifications resembling those of *Penicillium*.

Injections of Mould-spores into the Blood.—Grawitz injected spores of *Penicillium* and *Aspergillus* into the vascular system of rabbits, with the view of demonstrating their transformation into bacteria. He thus obtained the formation of small metastatic centres in the kidneys, liver, lungs, etc. The spores sent forth hyphæ which were able to produce imperfect organs of fructification, but failed to effect the formation of fresh spores. Gaffky, Koch, and Leber repeated these experiments, and showed that the acclimatization of any kind of mould in the interior of the system was impossible, whatever might be the more or less serious lesions produced by the introduction of foreign bodies into the blood of a warm-blooded animal.

Errors caused in Laboratory Experiments by the Involuntary Mixture of Different Microbes.—We should be the more cautious about accepting the real or apparent polymorphism of certain microbes, since the most scrupulous precautions do not always succeed in preventing confusion. Of this Klein gives the following instances.

While he was studying the microbe of anthrax in his laboratory at the Brown Institution, one of his friends was studying canine distemper in an adjoining room. This friend injected the blood of a dog affected by distemper into a guinea-pig's veins, and was surprised to see the animal die two days later with all the symptoms of anthrax, and to discover *Bacillus anthracis* in its blood. Yet he had made the injection with a perfectly new hypodermic syringe; while Klein, for his own injections, had made exclusive use of pipettes drawn to a point in the flame of a lamp.

In this case, it must be assumed that the bacilli and spores of anthrax had settled on Klein's clothes, had spread to the table and floor of the second cabinet, and had passed thence on to the guinea-pig's hair at the moment of the experiment.

Another operator, who inoculated a guinea-pig with human tubercles, worked at the same table as that on which Klein performed his experiments on anthrax. Two of the guinea-pigs died with *Bacillus anthracis* in the blood. Yet the pipettes in use had always been repointed in the fire, and all the other instruments had been thoroughly heated before the inoculation.

In another case, on the contrary, a guinea-pig inoculated with an attenuated culture of *Bacillus anthracis*, of which the effect could not be fatal, was examined at the end of some weeks, and all its organs were found to be affected by the bacilli of tuberculosis. On consulting his notes, Klein found that on the same day he had performed experiments on tubercular matter in the same laboratory, but he had always been careful to use different instruments. The same phenomenon was produced in a rabbit which died, not of anthrax, with which he was supposed to have been inoculated, but of general tuberculosis. The inoculating liquid had clearly been impure.

It is probable that Büchner's experiments on the bacillus of meat were vitiated by a similar error. Büchner inoculated mice with this bacillus, and believed that he had produced anthrax. But as he had performed numerous experiments on anthrax in the same laboratory, it is probable that his cultures of the meat bacillus were impure, and that he had really inoculated with *B. anthracis*. The transformation of the bacillus of meat into that of anthrax is therefore not yet proved.

Jequirity Microbe.—This is another instance of an analogous mistake, owing to which the Jequirity bacillus has been supposed to be transformed from a merely septic into a pathogenic microbe. This substance, recently imported from India, is extracted from the seeds of *Abrus precatorius*, one of the leguminous plants. A few drops of the infusion of these seeds applied to the eye produce conjunctivitis, which is artificially excited in order to effect the disappearance of the granules (*trachoma*) by which the inner surface of the eyelids is sometimes affected. In India, the same liquid is used to kill cattle by a simple puncture, with the object of skinning them.

When Sattler noticed that an infusion of jequirity became full of moving bacilli in a few hours, resembling *bacillus subtilis* of an infusion of hay (Fig. 80), he made cultures of this bacillus, and produced by their means serious ophthalmia in the eyes of rabbits. At the same time he ascertained that this microbe was harmless when floating in the air, and that its pathogenic properties were only displayed when it was cultivated in an infusion of jequirity.

In spite of this, Sattler ascribes the pathogenic action of this substance to the microbe.

Klein repeated his experiments with great care, and was successful in solving the contradictions which appeared to result from Sattler's researches. He proved that the bacillus of jequirity, taken by itself, could no more produce an infectious ophthalmia than Büchner's meat bacillus could produce anthrax. The poisonous principle of jequirity is a chemical ferment (*Abrine*), analogous to pepsine, and independent of any microbe, and its assumed bacillus probably does not differ specifically from *Bacillus subtilis*.

The transformation of an originally harmless microbe into a pathogenic microbe is therefore not yet proved, and all known facts contradict the possibility of such a transformation.

Septic and Pathogenic Microbes.—Hence we are led to define, more precisely than before, the terms septic microbes and pathogenic microbes, which are in current use in bacteriology.

The term "septic" is applied to the microbes or bacteria which generally live in decomposing organic matter and in dead bodies. These microbes, or their spores, are found in the air, in water, or the soil, in the mouth and intestinal canal of a healthy man or animal; but they are developed in greater numbers when the tissues are dead or in a diseased condition, and also in pus, in the bronchial secretion of pulmonary catarrh, on the surface of intestinal ulceration, etc.

Such are *Bacterium termo* and *Bacillus subtilis*, the microbes of putrefaction, those of the sweat of feet, etc., of which we have spoken above; such, again, is the bacillus of Büchner's meat infusion, that of Sattler's jequirity, and finally, Grawitz's *Aspergillus*, mentioned in this chapter.

These various microbes, inoculated or injected into blood, may indeed produce different disorders, which in some cases always remain local (*œdema*); in others are limited to metastatic centres encysted in various organs—the liver, kidneys, lungs, etc.; or, again, they may produce a general infection of the blood, as in the septicemia produced by Davaine when he inoculated rabbits with the fluid of putrid beef. These rabbits died within two days, and their blood was found to be full of *Bacterium termo*. The same result has been obtained by Pasteur and Koch, by merely inoculating guinea-pigs and mice with a little putrid earth or water, in which the same organism was evidently present. But in no case a disease with distinct characters was produced by this means, with special symptoms, epidemic or contagious, analogous to those of erysipelas, anthrax, tuberculosis, or cholera. Hence the name of *experimental septicemia*, since these diseases do not exist in nature.

On the other hand, those microbes are termed pathogenic which always characterize by their presence a special disease, epidemic or contagious, and possessing special symptoms and lesions, whether this microbe subsists in the blood, the inner part of the organs, or merely on the surface of the digestive canal. Such are the microbes of anthrax, of tuberculosis, and of cholera, natural diseases which are not produced by the experiments of man. Up to this time a septic microbe has not been proved to be transformed into a truly pathogenic microbe, and consequently a completely new disease, characterized by the development of this microbe in the body of man or animals, has not been created.

It must also be remarked—and this peculiarity is common to both classes of microbes—that certain bacteria produce very different effects, according to the animals into whose bodies they are introduced. Thus guinea-pigs cannot be inoculated with the experimental septicemia of rabbits and mice; and dogs and swine display more or less resistance to the inoculation of anthrax. Finally, there are cases in which the attempt to inoculate an animal with a contagious disease merely produces a septicemia which must not be confounded with it. This result will not astonish those who know that some species of plants, poisonous to man, can be eaten with impunity by many animals. But it is well to keep this fact in mind in laboratories, when the attempt is made to inoculate animals of various species.

CHAPTER IX.

CONCLUSION.

The Microbian Theory compared with other Theories put forward to explain the Origin of Contagious Diseases.

The parasitic theory of diseases is far from being generally adopted by medical men; at this very time the theory is actively opposed by medical practitioners of high standing, who are advocates of the theory of the innate character of diseases. In their opinion, the disease is spontaneously developed in the patient, or, at any rate, under the influence of a contagion of which the nature is still unknown. They consider that it is only a secondary complication when microbes are found in the blood, and that these microbes are not the cause of the disease, nor even the contagious element, nor the vehicle of contagion. In a word, the microbian theory is in their eyes a purely gratuitous hypothesis.

Admitting with them that the microbian theory is only an hypothesis, let us compare it with other hypotheses which have been proposed to explain the virulent and contagious nature of certain diseases. This comparison may throw some light on the question at issue.

The value of an hypothesis must be estimated by the number and importance of the facts of which it affords a clear, precise, and really scientific explanation; it must also be estimated by its influence on the advance of science. We will therefore enumerate the principal theories which have been proposed to explain the origin of virulent and contagious diseases, without the intervention of microbes.

Robin's Theory of Blastema.—Although, as far as we are aware, Robin has not recently published anything with reference to his opinion of the value of the microbian theory, some of his pupils have set forth the theory of blastema as it was stated by their master in books published from ten to twenty years ago.

In Robin's opinion, no cell is born from another cell, in the form of a bud, an egg, or a spore. Undoubtedly there is no spontaneous generation, at the expense of elements of exclusively inorganic origin; but this generation or genesis occurs every day at the expense of an organized substance which is living, but fluid and amorphous, and which has its source from other pre-existent cells. This fluid is termed *blastema* by Robin. Blastema is the surplus of the nutritive substance, organized by the cells and exuded from them. New cells may be completely formed at the expense of this blastema, without having their source in one cell more than in another. According to Robin's theory, the pus-corpuscles, which are a new creation, are produced in this way: they result from the exudation of a fluid which issues from all the organs, and are not produced by the enlargement, reproduction, and budding of pre-existent cells, as it is stated in other theories, and notably in those of Schiff and Cohnheim.

When this is established, it follows that all diseases have their origin in a chemical or physiological change in the blastema, which at one time produces normal cells, adapted to replace those which die from natural decay, and at another engenders diseased cells, which are dangerous, either owing to their too great number, as in septicemia, or from their peculiar nature, as in tubercle and cancer. Here we will quote Robin's words: "The cause of morbid disturbance arises from the changes which take place in the quantity and nature of the immediate constituents of the actual substance of the tissues and secretions. These changes make the development of minute spores possible. The multiplication of microscopic plants is a secondary phenomenon; not the scientific cause which actually determines it. The presence of the vegetable parasite is a complication which has been mistaken for the cause" (*Histoire naturelle des végétaux parasites de l'homme*, 1853, p. 287).

These words were written more than thirty years ago, and it may be asked whether the immense progress which science has made since that date has not somewhat modified the author's opinions. Jousset de Bellesme is scarcely entitled to take these words and paraphrase them as follows:—"The microbe, where it really exists, is only a secondary phenomenon, and it would not be too much to say that no fresh element has intervened, either in small-pox, scarlatina, or tubercular disease; in such cases there is only an exaggeration and reproduction of normal elements, which, influenced by wholly obscure conditions, are evolved in an altogether unusual manner."

The definition given by Jousset de Bellesme is not that of contagious diseases, but of those which are combined under the generic name of cancer. If he means to compare these diseases with cancer, such a comparison is impossible. It is well known that cancer is not contagious, and this fact alone places a gulf between these two kinds of disease. Cancer is not only not contagious nor is it conveyed by inoculation, but it is only hereditary in about a tithe of cases. Tuberculosis is, on the other hand, a contagious disease, because it is produced by microbes, and it may be set down as hereditary in nine cases out of ten.

Jousset de Bellesme's theory, therefore, explains nothing, and leaves the question absolutely untouched, since it throws no light on contagion and virulence, the precise points which it is essential to explain. But we must return to Robin's theory. When he states that the microbe is only developed in tissues which are already changed, Robin is not so far from the parasitic theory as his pupils represent him to be. It matters little that the microbe may be only a complication, a secondary phenomenon, if this secondary phenomenon dominates the whole disease and invests it with its dangerous character, its contagious and virulent nature. In the case of a viper's bite, it is not the bite from the animal's teeth which is dangerous, but the introduction of the venom which flows from them; that is, the secondary phenomenon. And it is the same with an anatomical puncture.

Two men in similar circumstances are attacked by pneumonia; the first will recover with ease because he is only thirty years old, while the other is almost certain to die because he is seventy-five, but we should not therefore say that he died of old age, and that the pneumonia was only a secondary phenomenon.

Oïdium and the phylloxera have attacked the French vineyards which are exhausted by excessive cultivation, but it will not therefore be denied that these are two dangerous diseases; nor should we say that they are secondary phenomena. It is therefore evident that Robin's theory, as it is set forth by his disciples, who have resuscitated statements made twenty or thirty years ago, is no longer on a level with the present state of science, and is in no case applicable to virulent and contagious diseases.

Theory of Charlton Bastian, and the English Followers of his School.—This theory, held by the most ardent opponents of the school of Tyndall and Pasteur, is set forth in the writings of Lewis and Lionel Beale. It scarcely differs from the one we have just stated. Lewis thinks it very evident that the presence of microphyta of the blood is only a secondary phenomenon; that the change in the fluids of the body is effected before the slightest trace of their presence can be discovered. This is plainly Robin's theory.*

Beale is still more absolute and exclusive.† He holds that the solid particles of vaccine are not bacteria nor micrococci, but *bioplasts*, or formulated elements which have their source in the living substance of the cow, and these bioplasts constitute the effective contagion of all virulent diseases. Bioplasts are extremely minute particles of the living substance of the species affected by the disease. The contagion is a *bioplasma*, and each species of contagious bioplasma manifests its peculiar specific action, and that only. We must leave it to others to admire and paraphrase this scientific jargon, which seems intended to take us several ages back. We must, however, observe that Beale's theory is somewhat allied to another, much more serious and complete, of which we have now to speak.

* *Les Microphytes du Sang*, 1881.

† *The Microscope in Medicine*, 1882.

Béchamp's Theory of Microzyma.—According to this theory, diseases are not due to a fluid blastema which is changed in disease, but to an organized and solid blastema, resembling the constituents of the blood, and consisting of very minute particles of living matter, which are *microzyma*. These are the elementary granules which may be seen under the microscope in the cells and in all the fluids of the organism. The mycrozyma, and not the cells in which they are encysted, are the real agents of all the functions of the organism. By the secretion of a fluid termed *zymase*, or ferment, by which they are constantly surrounded (both together constituting what is called protoplasm); these microzyma effect the various transformations which have for their final object the nutrition of the organism. Virulent and contagious diseases are not produced by parasites coming from without, but by the microzyma themselves, owing to a perversion of their normal functions. In such cases they secrete a vitiated *zymase*, and are transformed into micrococci and bacteria, which it is an error to regard as foreign bodies, since they are only the result of the special form of microzyma pre-existing in our tissues.

It must also be said that these microzyma are imperishable. The cells of our organism die and are renewed, but the microzyma which they contain are only associated with other microzyma in order to constitute fresh cells. After death, their transformation into microbes produces putrid fermentation, and their existence is prolonged far beyond that of the organisms of which they temporarily formed part. Thus the microzyma of chalk, which doubtless have their source in the animal and vegetable tissues of that epoch, are still living after a repose of many thousand centuries, and may be transformed into bacteria if supplied with the fitting nutritive liquid, as Béchamp has demonstrated.

This is undoubtedly a very attractive theory, which would explain a larger number of facts than the theories previously stated, yet it is impossible to make it agree with some of these facts, while they are readily explained by the parasitic theory. Such, for example, are the phenomenon of putrefaction, and the benefits of Lister's dressing, and of Guérin's protective method applied to wounds.

Robin, in his theory of blastema, also stated that putrefaction took place without the intervention of any external agent.

It is, however, now known that when dead bodies are protected from air-germs, they do not putrefy, but become mummies. Such is the case with the bodies which have been preserved for many centuries in the crypt of one of the churches in Bordeaux, and which, without any antiseptic preparation, have gradually passed into the state of mummies. Many underground buildings and caverns, in which the air is dry and the temperature invariable, present conditions favourable to such transformation, doubtless because this situation is unfavourable to the life of the lower plants.

The theory of microzyma explains the transmission of diseases by the organized elements of the virus, while the filtered liquid of the same virus is uninjurious, and in this respect it is more in accordance with facts than the theory of blastema; but it does not explain the effect of the exclusion or sifting of the air by Guérin's dressing, nor that of carbolic acid in Lister's dressing. In fact, if the virulent microzyma are in the patient's body, and have no external source, it is difficult to understand of what use this process can be. It is evident that the cotton wool, which only arrests the solid particles of the air, while admitting the air itself, must act by warding off something suspended in the air, and the matter in suspension can only be organized bodies, or air-germs.

Theory of Ptomaïnes.—Special alkaloids (*septine*) were discovered by Panum in pus and by Selmi and Gautier in putrefying matter (ptomaïnes), and partizans of the theory of non-organized virus appeal to these as a last resource. It has been supposed that these ptomaïnes or toxic alkaloids were the product of putrefaction, or morbid changes which were purely chemical, produced in the tissues and fluids of the system, without any external intervention of microbes. This *a priori* idea does not really differ from Robin's theory of blastema. If it is accepted, all pathogenic microbes resemble Sattler's jequirity bacillus, which certainly lives and is developed in the toxic juice of the seeds of *Abrus precatorius*, but which, as Klein has shown, has no influence on the artificial conjunctivitis produced by the aid of this liquid.

This theory of ptomaïnes without microbes is, however, inconsistent with an impartial study of facts. It is true that a suitable filtration will separate the ptomaïne from its microbe; but the converse, as in the case of the jequirity liquid, is impossible. When this microbe is separated from the original liquid, and transferred to the infusions of successive cultures, so as to purify it from every foreign element, it continues to produce its characteristic ptomaïne, which is manufactured completely at the expense of the culture liquid, as Pouchet's recent experiments on the ptomaïne of cholera have shown. There is no ptomaïne without its special microbe, any more than there is ergotine without *Claviceps purpurea*, or vinegar without *Mycoderma aceti*.

Pasteur's Microbian Theory is the only one which explains all Facts.—The microbian theory is the only one which is not obliged to have recourse to the vague expressions with which medicine was formerly content to explain the contagion of diseases, and which still satisfies Jousset de Bellesme, when he speaks of the wholly obscure conditions which accompany the production of these diseases. All the expressions of miasmata, virus, effluvia, etc., which were in use twenty years ago to designate that unknown agency which constitutes contagion, could only be defined by having recourse to the term "catalytic action," which merely placed the solution of the problem another step back, and substituted one unknown thing for another.* The parasitic theory will have done much for science if it only delivers us from "miasmata," "effluvia," and, above all, "catalytic action." As soon as it had been shown that miasmata and effluvia, as well as virus, were only air-germs—that is, microbes and their spores—a brilliant light was thrown on all pathology, of which the benefits may be measured by the great work accomplished in this direction within the last ten years.

This theory has given us Guérin's protective treatment of wounds, Lister's antiseptic dressing, and Pasteur's new vaccine, and these three great discoveries are enough to render the hypothesis immortal, even admitting that it is only an hypothesis. The adverse theories, when opposed to the microbian theory, can show us no progress effected in science, and this suffices to condemn them.

Moreover, the microbian theory is no longer in the primitive stage in which it can be regarded as a pure hypothesis, since it has entered the domain of positive facts. Before an infectious disease can be considered due to the presence of a specific microbe,

* See, for example, the article *Miasmes* in Nysten's Dictionary (*Littré* and *Robin*, edit. 1864): "Miasma is constituted by the *organic substances of the air*, in different stages of catalytic modification." These words are printed in italics by Robin himself. See also the words *Effluves*, *Catalytiques*, *Virus*, etc., in the same dictionary.

it is indispensable to submit it to the test of the four following rules, which have been clearly established by Koch:—

1. The microbe in question must have been found either in the blood or tissues of the man or animal which has died of the disease.

2. The microbe taken from this medium (the blood or tissues, whichever it may be), and artificially cultivated out of the animal's body, must be transferred from culture to culture for several successive generations, taking the precautions necessary to prevent the introduction of any other microbe into these cultures, so as to obtain the specific microbe, pure from every kind of matter proceeding from the body of the animal whence it originally came.

3. The microbe, thus purified by successive cultures, and reintroduced into the body of a healthy animal capable of taking the disease, ought to reproduce the disease in question in that animal with its characteristic symptoms and lesions.

4. Finally, it must be ascertained that the microbe in question has multiplied in the system of the animal thus inoculated, and that it exists in greater number than in the inoculating liquid.

These four conditions are necessary and sufficient, and in the present state of science they may be regarded as fulfilled in a considerable number of diseases: in anthrax, fowl cholera, swine fever, glanders, small-pox, tuberculosis, erysipelas, and even in Asiatic cholera. These are undoubtedly microbe diseases in every sense of the term.

The opposition which the microbian theory encounters in pathology is not new, and need not surprise us. In all ages medicine has clung to its old traditions, and has been unwilling to renounce the habit of regarding disease as something mysterious, just as in the times of ancient magic, of which our modern seers and sorcerers are a relic. The parasitic theory is too simple and natural to be accepted without a struggle, but its earlier achievements are a good omen for the future. We need scarcely remind our readers that at the beginning of this century the parasitic theory of itch encountered the same opposition, yet no physician now doubts that *Sarcoptes scabiei* is the sole cause of the disease. Somewhat later, towards the middle of the century, when the presence of special microphyta was ascertained in most skin-diseases, the importance of this discovery was denied; yet few physicians will now dispute that these microphyta are the chief, or rather the sole cause of these diseases.

So, again, in anthrax, when we observe the blood and all the organs filled with bacteridia (*Bacillus anthracis*), it can hardly be denied that this disease is essentially parasitic. Since these bacteridia are living beings which grow, are reproduced, and breed with great energy, it must be admitted that their presence constitutes an immediate danger, especially since it is known that they elaborate, at the expense of the organism, a violent poison (ptomaïne), which penetrates wherever the bacteridia cannot find their way. It can hardly be said that in this case the bacteridia are only a "secondary phenomenon;" that is, an unimportant complication which gives no cause for uneasiness.

What we have here said of anthrax also applies to other diseases: to diphtheria, small-pox, and intermittent fever. We venture to say, that if our instruments were not sufficiently powerful to enable us to see the organisms which cause these diseases, reason alone would oblige us to admit their existence, from our general knowledge of the cause and nature of contagious diseases. The word "contagion" implies microbe, and the simplicity of the theory gives it value, and permits us to regard it as the expression of actual facts.

After this, it is unimportant to know whether the microbe is itself the contagion, or only its vehicle; if it acts by itself, or only by the production of ptomaïne; if there is a specific microbe for each kind of disease, or if this microbe is susceptible of transformation, like other living things, according to the nature of the medium in which it is nourished. These are secondary questions, of which the future will doubtless afford the solution, but which do not affect the principle of the parasitic theory. That theory is only just established; each day brings a fresh stone to the edifice, but we must not yet expect it to be complete in all its parts. The advance of science may modify its details, but it may be asserted that the foundation itself will remain, since it relies on the simple and natural interpretation of facts.

APPENDIX.

A.

TERMINOLOGY OF MICROBES: VARIATIONS IN DENOMINATION AND CLASSIFICATION.

In consequence of the polymorphism of microbes, the terminology employed by different authors is very unstable. We have given the established morphological classification which is still most generally used, but we must here add some remarks which will make it more easy to understand the works recently published on microbes, such as *Les Bactéries*, by Cornil and Babès, and *Micro-organisms and Diseases*, by Klein.

We must first note the tendency to eliminate the names of two genera: *Bacterium* and *Vibrio*.

Cornil and Babès give the name Bacteria, which is the title of their work, to the whole group of *Bacteriaceæ*, or microbes strictly so called, regarded as a distinct order. They have consequently been led to suppress the genus *Bacterium*, in order to avoid confusion; and most of the species formerly assigned to the genus *Bacterium* are regarded by them as *Bacillus*, whether the individual is long or short, mobile or stationary. In the description of the microbes of human diseases, we have conformed to this nomenclature, which appears to be adopted by histologists, so as not to overload the synonymy of microbes, which is already somewhat encumbered. It is probable, moreover, that this assimilation is correct, and that most bacilli pass through a phase in which they are short and mobile, before becoming elongated and stationary. On the other hand, certain types of the old genus *Bacterium*—for instance, the bacteria in the form of an 8—should rather be assigned to the genus *Micrococcus*, or to the new genus *Diplococcus*.

With respect to the genus *Vibrio*, it seems to have been originally only a somewhat heterogeneous collection, comprising both the chains and chaplets of micrococci or of short bacteria, and the strictly unicellular organisms which might be assigned to the genus *Spirillum*. Klein, however, reserves this genus for *Vibrio rugula* and *V. Serpens*.

The genus *Micrococcus* (Hallier) is also termed by Cohn, *Spherobacterium*, and these two names are now given to the only unicellular microbes which are round or oval, stationary, and consequently devoid of cilium or flagellum, the organ of propulsion.

These micrococci may be in the form of chains or chaplets (*torula*), dumb-bells (Klein), the figure 8 (*Diplococcus*, Billroth), groups of four, and zoogloeæ or in masses of greater numbers.

The genus *Bacterium* (*Microbacterium*, Cohn) differs from the foregoing, as Klein states, chiefly in the oval or cylindrical form of its cells, and still more by the presence of a cilium or flagellum at one extremity, which gives a spontaneous movement. They may thus assume the form of a sponge-cake and of a dumb-bell when they divide in two, and may also form short chains or zoogloeæ. As we have already said, most of these organisms are assigned by Cornil to the genus *Bacillus*; at any rate, in the case of organisms peculiar to human diseases.

The genus Bacillus, according to Klein (*Desmobacterium*, Cohn), includes microbes in the form of more or less elongated rods, which divide by fission into straight, curved, or zigzagged chains, formed of elements generally in contact by their square-cut edges, and which may be considerably elongated in the form of *Leptothrix*.

Some of these, when isolated or in short chains, possess a flagellum at one extremity, and are consequently mobile—such is the case with *Bacillus subtilis* and most of the bacilli of putrefaction—but they lose this organ of movement on passing into the state of *Leptothrix*. *Bacillus anthracis* is always stationary, and devoid of flagellum. The fact that there is in this genus a vibratory cilium, and consequently motion, breaks down the barrier between the genera *Bacterium* and *Bacillus*, and consequently justifies Cornil's view.

The genera *Spirillum* (*Spirobacterium*, Cohn,) and *Spirochœte* are much more rare, and have not given rise to the same variations in nomenclature.

We conclude by reproducing the classification of Rabenhorst and Flügge, as it is given by Cornil and Babès, in order to serve as a convenient scheme for the pathogenic bacteria in which we are specially interested:

Classification of Rabenhorst and Flügge.

					Genera.
Round or oval cells.	Isolated, in chaplets or in zoogloeæ			... ...	*Micrococcus.*
	Forming zoogloeæ in the form of	Solid colonies filled with cells.	In large numbers and irregular colonies	... ...	*Ascococcus.*
			In small definite numbers and regular groups	... ...	*Sarcina.*
		A single circular layer ...		... ...	*Clathrocystis.*
Cylindrical cells.	Short, isolated, in a mass or in zoogloeæ			... ...	*Bacterium.*
	Forming long filaments.	Isolated, inter-laced, or in bundles. Not ramified. Straight filaments.	Short, jointed	...	*Bacillus.*
			Long, im-perfectly jointed. Slender		*Leptothrix.*
			Long, im-perfectly jointed. Thick		*Beggiatoa.*
		Isolated, inter-laced, or in bundles. Not ramified. Spiral filaments.	Short, rigid ...	...	*Spirillum* (*Vibrio*).
			Long, flexible	...	*Spirochæte.*
		Isolated, inter-laced, or in bundles. With false ramifications		...	*Streptothrix.* / *Cladothrix.*
		In zoogloeæ ...		... ...	*Myconostoc.*

B.

APPENDIX TO CHAPTER III. (p. 131).

MICROCOCCUS OF PHOSPHORESCENCE.

The phosphorescence of the sea is due to the presence of *Noctilucæ*, protozoaria of the group of *Flagellata*, which come to the surface in stormy weather. Many other marine animals present the same phenomenon. The phosphorescence of rotten fish is due to the presence of a special micrococcus which forms large circular zoogloeæ. The same micrococcus also appears on putrefied meat and imparts to it a phosphorescent light.

C.

APPENDIX TO CHAPTER III. (p. 131).

PLANT-DISEASES CAUSED BY BACTERIA.

The presence of parasitic bacteria has been recently pointed out as the cause of diseases in plants. In 1880, Burril, of Illinois, U.S., has declared the shrivelling of pears to be due to a bacterium which attacks fruit-trees, and of which he succeeded in making an artificial culture. In 1882, the *jaundice* of hyacinth bulbs was ascribed by Wakker, of Amsterdam, to the development of a bacterium between the layers, which may finally destroy the plant. In August, 1885, Luiz de Andrade Corvo presented a paper to the Academy of Sciences, in which he asserted that the vine-disease ascribed to *Phylloxera vastatrix* is really due to a bacillus, or rather, according to his description, to a bacterium, which is always found in the tubercles of the radicles and in the tissues of the vine which are affected by this disease, termed by him *tuberculosis*. They are also found in the body of the insect, which thus becomes simply the agent of contagion.

Neither Wakker in 1882, nor Burril in 1880, was the first to point out the presence of microbes in the diseased tissues of plants. As early as the year 1869, Béchamp noticed the presence of *microzyma*, that is, bacteria, in the affected parts of plants (*Comptes rendus de l'Academie des Sciences*, vol. lxviii. p. 466).

D.

APPENDIX TO CHAPTER IV. (p. 143).

PTOMAÏNE OF THE MICROBE OF FOWL CHOLERA.

Duclaux cites the following fact in his book, *Ferments et Maladies*:—"If a fowl is inoculated with a few drops from a culture of fowl cholera, the bird sickens and dies; but if the liquid has been filtered before using it, through plaster or porous china, the disease produced is not fowl cholera. The bird rolls himself up and falls into a passing sleep, from which he is roused by the slightest noise.

"After a few hours, his recovery is complete. Thus there are two kinds of symptoms in fowl cholera, of which the most apparent is due to a species of narcotic (ptomaïne) secreted by the microbe, but capable of independent action, and not in general ending fatally."

E.

APPENDIX TO CHAPTER V. (p. 171).

CESSPOOLS. SYSTEM OF CARRYING EVERYTHING TO THE SEWERS.

This system, so long advocated in Paris by Durand-Claye, implies that the water should pour into the receptacles, so as constantly to flush the drain-pipes. A minimum of ten litres per diem to each inhabitant is necessary for this purpose.

The household water and rain-water likewise pass into evacuation pipes of the sewer by sypecial sphons, and help to flush them. This system has been applied to the Hotel de Ville, to the new Guards' barracks, to a certain number of primary schools, and to many private houses. The municipal administration proposes to apply this system to most of the schools, hospitals, and barracks, of which the sanitary condition is at present far from satisfactory. They hope eventually to extend the same system to all private houses, so as to do away with the cesspools—a reform already effected in many foreign cities, and notably in Germany.

F.

APPENDIX TO CHAPTER V. (p. 172).

THE SEWERS OF PARIS AND THE PLAIN OF GENNEVILLIERS.

The water issuing from the main sewer of the city is partly turned into the Seine, partly into the plain of Gennevilliers, and used, by a system of irrigation, for fertilizing the soil. There was some fear lest the vegetable mould might be saturated with fertilizing matter, but the presence of a special microbe was ascertained, which reduces organic matter to its inorganic constituents, and thus adapts them to be absorbed by plants. Schlœsing and Muntz, who have studied this microbe, term it the nitrifying microbe. The same system of sewer-irrigation will shortly be applied to another place in the neighbourhood of Paris, Achères, near the forest of Saint-Germain.

G.

APPENDIX TO CHAPTER V. (p. 172).

USEFUL MICROBES.

We have said that numerous bacteria exist in the digestive canal of a man in good health. Recent researches by Duclaux, Richet, and Bourquelot tend to show that these microbes are not only innoxious, but that they play an active part in gastric digestion, and especially in the transmutation of albumins into peptones. Since they are, in fact, living ferments, the transmutation is retarded, if these microbes are eliminated. It is therefore probable that they manufacture pepsin.

Pasteur's experiments also tend to show that microbes aid the germination of plants. If the microbes contained in vegetable mould are withdrawn from it, without taking away any other constituent, germination is retarded, and effected with difficulty.

H.

APPENDIX TO CHAPTER V. (p. 241.)

PTOMAÏNES OF FISH.

Salt and smoked fish often produce in those who eat them violent poisoning, which may even end in death. Aurep, of Kharkov, has recently studied these causes, and ascribes them to a ptomaïne secreted by a microbe, or perhaps evolved from the fish itself during life, under the morbid influence of this microbe.

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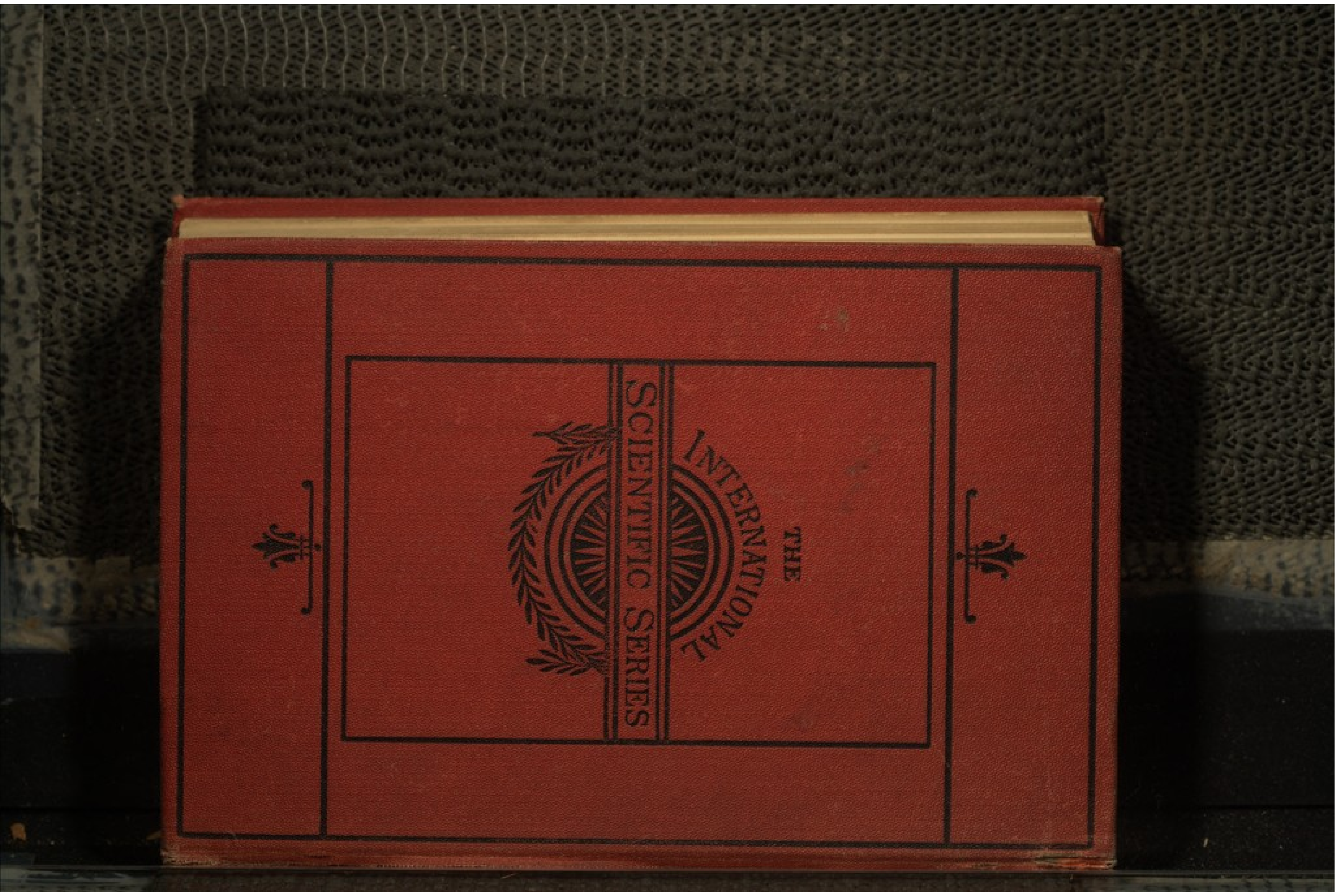
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