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THE STORY
OF THE
BACTERIA

T. MITCHELL PRUDDEN, M.D.



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The Story of the Bacteria

And their

Relations to Health and Disease

By

T. Mitchell Prudden, M.D.

*THIRD EDITION, REVISED AND ENLARGED
ILLUSTRATED*

G. P. Putnam's Sons
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1917

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PREFACE

TO THE FIRST EDITION

THE bacteria are so often nowadays the subject of discussion and discourse; so much which is at once disquieting and untrue is said about them, and they are withal of such practical importance to the health and well-being of everybody, that it has seemed to the writer worth while to bring together in some simple fashion a little of our knowledge about them.

The aim then of this book is to present some facts from a small corner of the domain of Science in such form as will be plain to the unscientific, and with these some extracts from the lore of the physician which will, it is hoped, be both interesting and useful to the lay reader.

T. M. P.



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PREFACE

TO THE SECOND EDITION

SOME twenty years ago, when the first edition of this little book was issued, bacteriology was in its early infancy. It is an infant still, but grown more lusty and articulate. These minute plants, the bacteria, logically belong in the purlieus of the botanist. But he has always turned the cold shoulder to them.

So at first they were popularly regarded as the foster children of Medicine. But little by little, the arts and the industries and the farmer have found them out so that to-day this modest bailiwick of the biological sciences, which we call bacteriology, is held in trust by a syndicate of scientific folk, of whom the medical men are perhaps the most conspicuous.

Our tread along the pathways which bacteriology opened has become firmer as the

years have passed, and out of its revelations we have won treasures of knowledge, of insight, and practical beneficence to man, which lie far beyond even the dreams of an earlier day.

While the revision of the book, for this second edition, has been everywhere extensive, the greater changes and additions have been made in the sections relating to disease and its prevention.

The addition of pictures and the enlarged scope of the book, it is hoped, will make it useful to the new generation of readers, whose outlooks for increased efficiency and happiness in life, is curiously interlinked with the performances of these invisible earth neighbors of ours, whose story is here briefly rehearsed.

T. M. P.



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The Story of the Bacteria



THE STORY OF THE BACTERIA

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CHAPTER I

THE CELLS OF THE HUMAN BODY—WHAT THEY ARE, AND WHAT THEY DO

BEFORE beginning to study those lowliest and smallest forms of life, the bacteria, I wish to ask my reader to look with me in this chapter at some of the higher and more complex forms of living things. In doing this we shall be following the course which scientific research has taken, and from the vantage-ground thus gained we shall be able the more easily to spell out the simple but significant story of the bacteria, which it is the purpose of this little book to tell.

In general anatomy we learn that the body consists of a bony framework, around which

various tissues and organs are securely and compactly grouped. When we have learned the size, shape, number, relations, and names of all these parts, our study of macroscopic or general anatomy is done. If, however, entering that department of science known as histology, or minute anatomy, we trace the manner in which these parts are made beyond the point where the naked eye can avail us, we find that they are all composed of certain tiny organisms called cells, and that these cells are held together and associated by certain materials which lie between them.

Just as the chemist has his atoms and molecules, to which in the last analysis he refers the properties which all known substances possess, and explains by differences in their nature and movements the various chemical phenomena which matter exhibits, so we may refer both the structural features and all the activities of the animal body back to the structure and activities of our elements—the cells. While the chemist, however, must infer the existence of his atoms from their deeds, armed with the microscope we can see our

cells, observe the things they do, and definitely trace out their life-history.

Cells are little masses of matter of peculiar chemical constitution, and of varied shape and consistence, which at some time exhibit that complex of phenomena which we call life: and the life of one of the higher animals is simply the sum of the more or less independent but co-ordinated lives of the cells which compose it, all acting in harmony.

Living things differ from the non-living in that they have certain activities through which their life is expressed. In the first place, they are capable, in spite of various opposing forces, of maintaining their individuality, and by holding a balance between waste on the one hand and assimilation on the other, a series of capacities arises which we call nutrition, growth, and development. Living things, in the second place, possess certain activities by means of which they are capable of producing new individuals like themselves—in other words, they are endowed with the power of reproduction. Lastly, living bodies, in response to varied influences, are capable of

doing certain things in the way of movements or of elaboration of peculiar chemical products, etc., and these are called their functions.

It will be observed that in enumerating these activities I have spoken of them not as characteristic of man, or of any special animal or plant, but of living things in general. All life finds expression in these ways. The means by which the living being does these things may be in one case exceedingly primitive, and in another very complicated, but this does not alter the essential character of the ends which it achieves.

If you tie a bit of muslin over a water faucet and allow the water to trickle slowly through it for a few hours, you will find on removing it that a more or less abundant greenish scum has collected on the cloth. Wash this carefully into an open dish, and let it remain for a few days in a light warm place, and then examine the sediment under a microscope, and you will find a very celebrated creature. It is called an amœba. It looks like a little lump of transparent or slightly granular jelly. You will see it thrusting out portions of itself

in the form of longer or shorter arms, and then withdrawing them and sending out others in another place, apparently in the most aimless way; or you may see it rolling itself over and over, or, if I may so say, flowing along so that it travels with considerable speed. Perhaps some microscopic vegetable may lie in its way, and it will flow over and enclose this, and, after digesting portions of it, expel the residue from whichever side or surface of its body may be most convenient. If, in a quiescent condition, it be touched by an external object, you may see it move in direct response to the irritation. If you are fortunate in your observation, you may see a constriction appear around some part of the lump, which grows gradually deeper until a portion of the mass separates from the rest and crawls off on its own hook as a new and independent amœba. It has no lungs and yet it breathes; no mouth, still eats; no definite shape, yet grows; no nerves, yet is sensitive; no sex, yet may give birth to endless progeny.

Now this amœba is one of the lowest and simplest of creatures, and is the type of a

cell—a creature which is composed of a single cell—and all the activities which I have mentioned as characteristic of living things are exhibited in it. It is a perfectly independent being, doing everything for itself, and doing nothing particularly well, except, perhaps, performing the function of reproduction, which it does with such ease and nonchalance as leaves little to be desired. The young which it produces are just like the parent, single cells, and their very first post-natal act may be to give birth to other amœbas.

Now let us advance a step in the scale of being, to an animal composed of several cells. There is a little creature, one of the group of sponges, called olynthus. Let us start with the ovum of the animal, which is a single cell, not very unlike the amœba in appearance. Under suitable conditions, this cell divides as the amœba does, and two cells are produced, just exactly alike. They do not separate, however, as do the amœbas, to become independent individuals, but remain fastened together; then each cell divides again, and these still further, until we have a little mass

of cells all looking alike, and the whole somewhat resembling a mulberry in shape. But now a change comes; the cells on the outside become longer than the rest, and little hair-like processes, called cilia, grow out from them and begin to vibrate to and fro, and, acting like tiny oars, propel the little creature through the sea. Presently the rest of the cells arrange themselves so as to form a central cavity, with an opening at one side, the whole looking like a tiny cup. The animal now attaches itself to a sea-weed or a rock, and no longer needing the locomotive cilia, they disappear; but as it can no longer travel, it can no longer seek its food, which must be brought to it. Accordingly we presently find that through the sides of its body little holes appear, and the cells lining the central cavity lengthen and develop cilia, whose vibrations maintain a current of water through the body, which brings with it oxygen and food. This is the adult olynthus.

Now observe, if you please, what has happened in the development of this little creature. A single cell divided into several cells, at first all just alike, and all doing the same

thing. But soon, as if in response to the growing needs of the animal, certain of the cells developed a special apparatus, and a special capacity for performing rapid movements, and this capacity was associated with changes in the form of the cells,—a specialization which signaled its advance to a higher type of existence.

Just here we come upon the great principle, in a very simple form, upon which the enormous differences between higher and lower animals rest,—the principle of the physiological division of labor in cells. The more perfect the individual is, the more elaborate do we find the expression of this principle.

The difference between the amœba and the olynthus from our present point of view—that which makes of the latter a higher animal than the former—is that it has a certain group of cells set apart to do a special thing, to move rapidly; amœba moves, but not so rapidly nor with such directness. If another group of cells were set apart in olynthus to do the digesting, no new cell powers would be developed which the amœba does not possess; the

primitive assimilating power would simply be specialized and intensified, and the animal would have risen to a higher grade of being.

It would not be difficult, did space permit, to trace the manner in which, as we pass upward in the animal series, certain groups of cells become more and more elaborate in structure as they assume higher and more specialized capacities. We cannot tarry for this, but will glance for a moment at the exhibition of this principle in the development of man. In man, too, life commences in a single cell called the ovum; a cell which, though harboring potentialities of the highest order, in many respects greatly resembles our little denizens of the water. This cell, under suitable conditions, divides and subdivides, forming a little cluster of cells all looking alike. Then these cells arrange themselves in layers; some of them assume special forms as they increase in number, and develop special capacities, and group themselves to form the various tissues and organs of the mature body, which finally is formed of a grand community of co-ordinated groups of cells, some of which have acquired

the power to do special things in the most perfect way, while others have remained in a condition of comparatively low organization.

Let us look at two examples of these two types of cells from the adult body—first at certain muscle cells. These in the very young animal look just like many other cells; they are individuals, they are alive and their life finds expression, just as the amœba's does, in certain activities—nutrition, growth, function, and reproduction. Presently they become longer than their neighbors, little striations appear along their sides, they grow long and narrow until at last they are little thread-like bodies with a very complicated internal structure, and are grouped in bundles to form the muscles as we see them with the naked eye. The peculiarities of structure of these muscle fibres are necessary for the performance of the work which they have specially to do—namely, the accomplishment of rapid and powerful movements. Now the capacity of the muscle cells for doing this work has been acquired, if I may say so, at the expense of some of the other capacities which they originally possessed

in common with other cells. Thus the power of reproduction is in them almost if not quite completely absent. They can also no longer seek out and take up crude food, but it has to be prepared for and brought to them, and in order that this may be done certain other cells in the body develop the power of elaborating a peculiar fluid—gastric juice, which helps to change the crude food so that it finally becomes fitted for the nourishment, among others, of the special workers, the muscle cells; other cells—the red blood cells—develop the capacity of bringing them oxygen, and in doing so have lost many capacities which are possessed by lower forms. Other cells develop in a peculiar way to form the nerves by which all the various parts of the body are brought into harmonious action, and so on. Thus we see in the higher animals each highly developed cell working for the others as well as for itself and for the organism as a whole, only its chief endeavor is concentrated in some one special thing, and as a result of this concentration some of the more general cell powers are lost or diminished.

Did time permit, I should like to picture for you the character and destiny of some of the lower forms of cells, which we find in the human body,—those which have not undergone that differentiation in structure and function which belongs to higher types; to speak of the marvellous potentialities which are dormant in them; to show you how their very simplicity of existence, the absence of special powers, and their boundless capacity for reproduction particularly fit them to become the conservators of the individual; to indicate what an important rôle some of them play in the healing of wounds and in the formation of new tissues. So we are not to think of the lower forms of cells in the body as insignificant, because under ordinary circumstances their being and performances are humble and inconspicuous, for they seem to be ever ready, either resting quietly in their tiny nooks within the solid tissues, or driven restlessly in the rushing torrent of the blood, to assume again the lowly but active powers of embryonic cells, and begin when necessary the work of reproduction and repair.

These cells have, too, a most important rôle, as we shall see by and by, in combating the incursion of certain forms of bacteria which now and then obtrude themselves into this happy family of cells which makes up the human body.

We have thus seen that all the varied structures and functions of the human body are but the combined expression of the structure and lives of the cells which compose it, all co-ordinated and working in harmony by means of a self-built, cellular mechanism. Starting with the type of the most simple of living things, a single cell, the finished organism is an aggregate of the progeny of the original cell, some groups of which have developed special forms and powers, in accordance with a universal principle in nature. So the doctrine of evolution, even should the record of the rocks be incomplete and perfect continuity in the grouping of living species fail, still finds epitomized in every animal and plant which has escaped from the primitive simplicity of the lowest forms, a most pertinent illustration and convincing proof.



CHAPTER II

BACTERIA AND SOME OF THE THINGS WHICH THEY DO

THERE are many very good reasons for believing that when life first appeared upon the earth it showed itself in a very simple and primitive form, in some such form perhaps as we have seen in the amœba or other simple cells. But as the ages passed, in accordance with the principles of the physiological division of labor, which we have glanced at in the last chapter, many of the living beings gradually assumed more and more complex forms and capacities.

Not all living things, however, shared in these evolutionary changes. There is, in fact, a great group of lowly plants, so small as to be quite invisible to the naked eye, and which until within a few years have been entirely

unknown to man, which still linger in the primitive simplicity which we imagine to have belonged to the earth's earliest denizens. These are the bacteria.

So small are the bacteria, and so simple in their structure and activities, that it has not been an easy task for scientific men to decide whether they belonged among animals or plants. It is now definitely settled, however, that they are plants, and are closely related to the seaweeds.

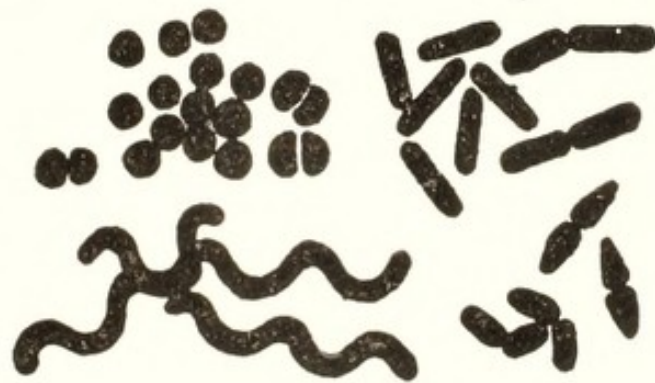


FIG. I.—FORMS OF BACTERIA

Bacteria vary a good deal in shape, but in general they are either spheroidal or ovoidal, like a billiard-ball or an egg; or rod-shaped, like a lead-pencil; or spiral-shaped, like a cork-screw. Some are separate, some clustered. Fig. I.

They are in general so very small that we can hardly form a conception of them except by comparison with some well-known objects.

One of the most common of the bacteria is a little rod, so small that if you were to put fifteen hundred of them end to end, the line would scarcely reach across the head of an ordinary pin. If you look at them with a magnifying power so great that, if it could be applied to him, it would make a man look about four times as tall as Mount Washington, they do not look larger than this dot (·). We can see, however, that they are made up of a slightly granular material surrounded by a somewhat denser envelope.

The bacteria appear under the microscope as pale translucent bodies, and the student usually finds it necessary, in order to see their outlines clearly, to stain them with some one of the aniline dyes—red, or blue, or violet,—when they become very distinct.

When they are alive and suspended in fluids many of the rod-like and spiral bacteria can perform the most elaborate and astonishing series of movements. They swim slowly, they turn about, they roll over, they wriggle, dart forward, retreat, bang against one another, rest awhile, sway to and fro, plunge off again,

and so on through varying phases of movement until the head swims and the eye tires in following them. This movement, in some of the bacteria at least, is induced by a little hair-like projection from the end of the organism, which vibrates rapidly to and fro—Fig. 2. It is very difficult to see these little projections or flagella, even with the most powerful microscopes, but, notwithstanding this, they have actually been photographed, and in some cases the image of the flagella, which failed to make an impression on the retina, has been caught and fixed by the sensitive plate in the camera.

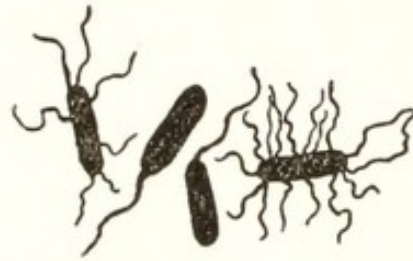


FIG. 2. — FLAGELLA OF BACTERIA

Warmth, moisture, oxygen, and some organic matter are the simple conditions required for the activities of the bacteria.

When the conditions are favorable they may increase in number to a degree which is limited only by their surroundings. A little constriction appears around one of the bacteria; it grows a little longer, a partition forms across

the middle, and in the place of one there are two full-fledged bacteria. These may at once fall apart and each new individual go on dividing as before, or they may cling together, forming threads or chains of varying length, or clumps or masses.

So rapid is this mode of reproduction that a single germ by this process of growth and subdivision may give rise to more than sixteen and a half millions of similar organisms within twenty-four hours. It has been calculated by an eminent biologist that, if the proper conditions could be maintained, a little rod-like bacterium, which would measure only about a thousandth of an inch in length, multiplying in this way, would in less than five days make a mass which would completely fill as much space as is occupied by all the oceans on the earth's surface, supposing them to have an average depth of one mile.

Let not the timid soul tremble, however, for the principle of the survival of the fittest and the influences of environment have kept our prolific organisms so well in check that the world had grown very old and its favored

nursling, man, pretty well along in experience and skill before ever he recognized the existence of these his microscopic contemporaries and possible ancestors.

The struggle for existence goes on, where varying forms of bacteria are growing, as fiercely as ever it did among more highly organized beings. One race succeeds another, one species adapts itself to the conditions which brought about the extinction of its predecessors. Hardy individuals struggle with their weaker neighbors as the food grows scanty in their microscopic seas, and the weaker goes to the wall.

Many forms possess the power of living and multiplying in the manner described above so long as the proper conditions prevail, but when life, owing to some change in the environment becomes no longer possible, the vital powers collect themselves in a little shining mass in one end of the bacterium, which surrounds itself by a dense membrane, and in this form, which is called a spore,—Fig. 3,—it can survive adverse conditions which in the ordinary form would have destroyed its life. Restore it

to the needed conditions and the spore swells into a bacterium again, and the roots of a new ancestral tree begin to sprout.

These bacteria are really very simple forms of cells, and like the cells which we have looked at in the last chapter, their life expresses itself in certain activities; they move, they nourish themselves and grow, they reproduce their



FIG. 3.—SPORES IN BACTERIA

kind. They have the power in carrying on the processes of their own nutrition, when moisture and air are present, of tearing to pieces, in the chemical sense, dead organic material, using up such parts of it as they need for their own purposes, and setting free the rest in such form as to be available for the use of other living things.

Everybody knows who thinks about it, that the supply of such material as makes up the bulk of the tissues of man, animals, and plants, on this earth, is limited. So that if things were not so arranged that living beings should have the use of the material which goes to make up

their bodies for only a comparatively short time, the supply would run short and new beings could not continue to appear.

When that mysterious group of activities which we call life ceases to be manifested, in animals and plants alike, if moisture and oxygen and sufficient warmth are present, that process known as putrefaction or decay begins, by which the old combinations of matter are broken up and the material set free for the use of other beings. Now just here enter the bacteria. It is they who tear these old organic compounds asunder, using a little of them as may suit their own needs, and turning over the rest to their earth neighbors, who have got higher up the scale of being, but not yet so far as not to need absolutely and hourly oxygen, hydrogen, nitrogen, and carbon, to keep their life's furnaces a-going.

It is a very motley group of chemical substances which these bacteria set free in feeding themselves on nature's waste organic materials. Sometimes these are very bad-smelling gases, sometimes aromatic substances, sometimes they are sweet, sometimes they are

sour. But sooner or later they are used by some animal or plant, and so again enter the domain of life.

Thus ever in ceaseless alternations between life and death these elemental combinations come and go. And ever since life emerged from its primal simple forms on the earth, the bacteria have silently gone on tearing the worn-out and useless to pieces and turning it over in new combination to other forms of life.

It was formerly believed that such lowly organisms as the bacteria could spring at once into being wherever in nature the conditions were favorable, but this notion of spontaneous generation has long since been given up, because it was shown to have depended upon insufficient and crude observation. We now believe that every living thing comes from some pre-existing living thing, be it man, beast, plant, or cell, and this principle holds true as well among the bacteria as among more highly organized beings.

There is an enormous number of different species of bacteria, each one of which appears to

preserve its individual character under all the varying conditions and vicissitudes to which it is subject. They are to be found everywhere in nature. Where putrefaction and decay are going on they are most abundant, but where any form of life can exist they are present, either dry and inactive, or where moisture and food are present, growing and multiplying in such degree as their surroundings will permit. In all natural surface waters, in the soil, on all fruits, vegetables, and plants; in the nose, mouth, digestive canal, and excreta of men and animals; on the skin, wherever dust can go or collect, there are bacteria of various forms in greater or smaller numbers. They are the scavengers in the economy of nature.

The great bacterial laboratory of the earth is the soil. Here the most wonderful things happen under the friendly influence of these tiny germs. With the aid of other lowly living things, they help in the gradual erosion of the rocks, from which the mineral ingredients of the soil arise. They pull the tissues of dead trees and plants and animals asunder,

setting free moisture and gases, and working the whole stuff over into the vegetable mould, from which the farmer wins a living for us all. Sometimes the farmer deliberately sets the bacteria at work, through the silos in which his crops are made more useful for the food of cattle. He keeps them busy in his manure heaps, which they "ripen" for the special needs of the soil. He uses them in making vinegar.

One of the most important of the chemical elements in the growth of plants, as we shall see more fully later, is nitrogen. In the water and earth certain bacteria manipulate nitrogen in the most astonishing fashion, getting it finally into proper shape for the uses of plant life.

It is bacteria which make milk turn sour. Other forms give to butter and to cheese their distinctive flavors. Some of them help the farmer in the ways which we have spoken of and in many others. But there are bacteria which play him false. His fruit decays when they get inside through bruises. They injure his vegetables when they find a chance. His meat and milk and eggs go bad, when the

wrong sort of bacteria get at them. His fence posts, his timber, and even his planted seeds rot; his hay heats and mildews; his water tanks get foul,—all through the action of bacterial pests. But in the long run the beneficent bacteria win out, if the farmer bacteriologist knows what to do and when to do it, and stands by his job.

The folks who tan leather, those who rot the flax plants to get them ready for the making of linen thread, and the people who cure the tobacco leaf for the smoker's delectation, are all jugglers on a large scale with capacities and whims of special forms of living bacteria. On the other hand, sugar manufacturers and bakers are often greatly pestered by the presence of certain bacteria, which hamper their operations or damage their products. The canning industries are engaged in a ceaseless warfare with bacteria which sometimes destroy their stuff and disgust their customers.

So common and abundant are the bacteria that we are constantly taking enormous numbers of them into our systems with all of our

uncooked food. We should not, however, think of these little organisms which we thus unwittingly consume as things necessarily unclean or unwholesome. For they are only little cells after all, and nearly all the food which we consume, whether animal or vegetable, is made up of masses of cells which are either fit to eat in their natural condition, as in the pulp of fruits, or become so by simple cooking or other preparation.

There is really very little difference, so far as wholesomeness is concerned, between the few thousand vegetable cells which we call bacteria which may be clinging to the surface of a grape, and a few hundred vegetable cells of larger size of which the grape itself is composed. Both are alike worked over by the digestive organs, under ordinary conditions, into nutritive material for the uses of the body.

There are poisonous vegetables, and there are, more 's the pity, as we shall see by and by, poisonous bacteria, but we do not shudder as we swallow a mushroom to think what might have happened to us if we had swallowed



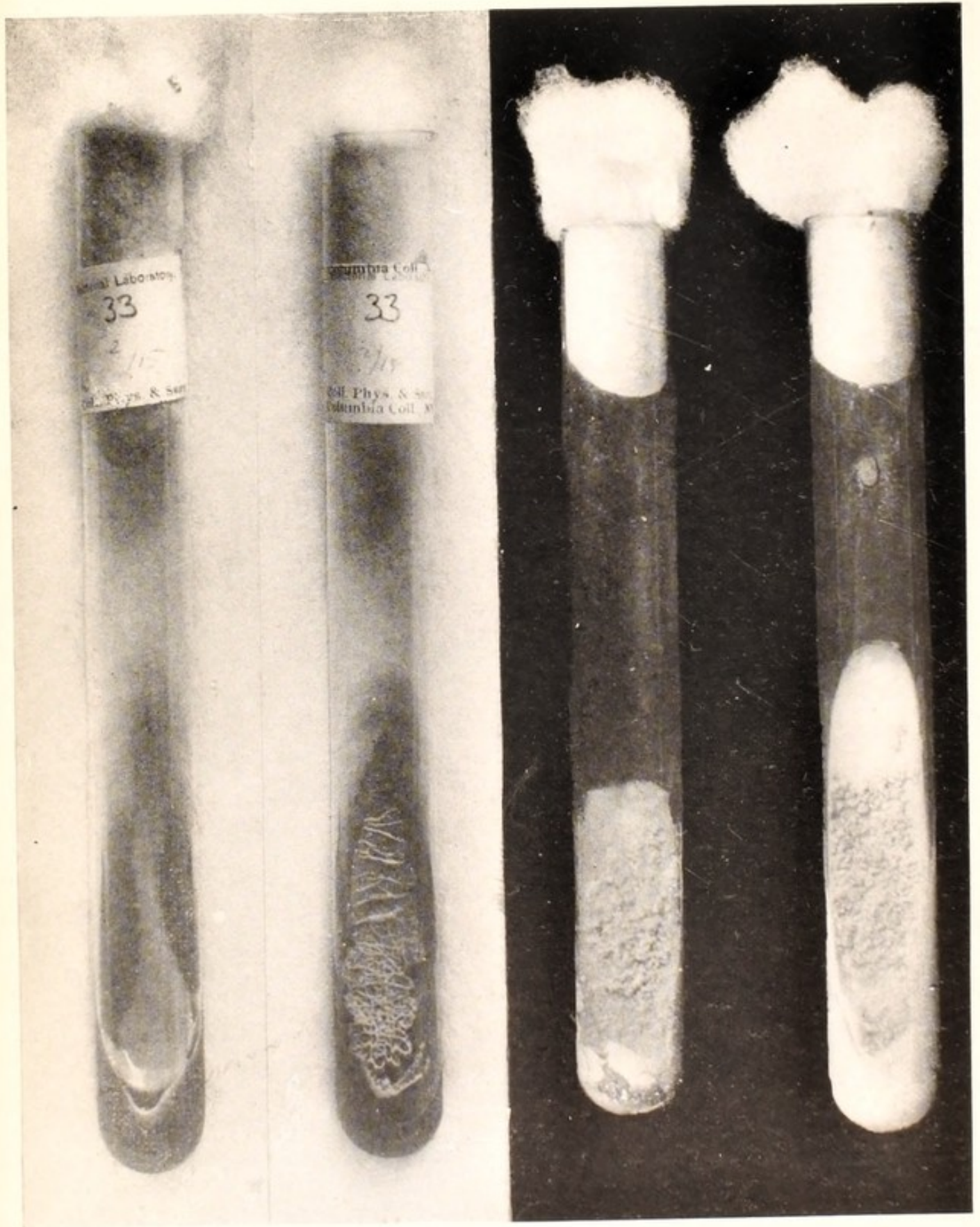


PLATE I.—TUBE CULTURES OF BACTERIA

The two tubes at the left contain gelatin culture medium and show different ways of growing of two species. The tubes at the right show a rough surface growth on a white egg mixture. Notice the cotton plugs which allow the air to enter but keep out all contaminating germs from the pure cultures.

a poisonous toadstool instead. We simply trust to the gardener, or, if he be dishonest or ignorant, see to it ourselves that the poisonous are not liable to get in with the other plants, and then go on enjoying our delicacies like sensible people.

It will thus be seen that the rôle of the bacteria in nature, though humble and silent, is an exceedingly important one. They are indispensable to the continuance of the higher forms of life upon the earth. They may well be called, in general, man's invisible friends; for without them the earth would soon be depopulated and lapse into what at first it was—a lifeless waste.



CHAPTER III

HOW THE BACTERIA ARE STUDIED

IF you take a small wisp of hay, put it in an open jar, and, covering it with water, set it in a warm place for a day or two, you will presently see that the water which was at first perfectly clear, begins to get turbid, and, after a while, a grayish scum collects on the top. Now the water begins to give off a disagreeable odor of decay. This is what has happened: The bacteria of various forms, which, in the dried condition, were clinging to the hay, or which were in the water, have multiplied to such an extent that they made the water turbid, and many of the mobile forms have sought the surface, where the oxygen was most abundant. The solution of organic material from the hay has furnished an abundance of food, and as the bacteria

have torn this into simpler forms to get the particular elements which they needed for their own use, the freed material, in part in the form of bad-smelling gases, has either been set free into the air or remains absorbed in the water.

If you examine a tiny droplet of the water from time to time with the microscope, you will find that it is swarming with various forms of bacteria, rods, balls, and perhaps spirals, many of them in active motion. But you will notice that from day to day the prevailing forms change. One day the little rods will be most abundant; the next, these may have largely disappeared, and perhaps the little balls are the most common forms. Then perhaps a new set of rods or balls will appear of a different size from the first. After a while you will find that the bottom of the jar has become covered with a light-colored sediment, and the water has become clearer.

The bacteria of one form or another have gone on dividing and subdividing, breaking up the dissolved organic matter in the water until either they had used up the special form of

material which was best suited to their needs, or until the material which they had set free had so far accumulated as to prevent their further growth, and then they died, self-poisoned, just as a man might who should be shut up in a tight room until the accumulation of the products of his respiration and excretion had made further life impossible. Or they may die because other species of bacteria growing in the same fluid furnish material which poisons their neighbors. So the procession of life goes on, until the bottom of the jar becomes a veritable graveyard of races.

Some forms of the bacteria, however, which seem dead, and fall with the rest to the bottom of the jar, are really only in a resting stage; they have formed spores within themselves in the manner described above, and may lie dormant until the proper conditions come again, when they may spring into renewed activities. But new species may from time to time fall into the jar from the air and find in the water, which was rank poison for the dead species at the bottom, just the food they need,

and so will the drama of life and death be enacted anew for long periods.

In such a confusing mixture as this the student finds it no easy task to make out much except differences in form and movement, in the jumble of tiny plants. What he needs to do is to get each species by itself, so that he can cultivate it alone, and find out what it is and does under more simple conditions.

For this purpose it is best to use some solid substance on which bacteria will grow.

Boiled potatoes, which have been carefully cleansed and sterilized—that is, free from any bacteria from the soil or air—by steaming, will do very well for some bacteria. These are cut in halves, with knives sterilized by heat, being held in the fingers which have been freed from living germs by washing with corrosive sublimate, and placed under sterilized bell-jars or in tubes, so that they may not be contaminated by the accidental falling upon them of bacteria from the air. Now, by means of a platinum wire set in a glass handle, which has been sterilized by heating to redness, a tiny bit of the bacteria-containing

material is spread upon the cut surface of the potato, and the latter is covered again and set away for a day or two in a warm place. Usually at the end of this time, if all goes well, there will be a growth of the bacteria on the potato so large as to be quite visible to the naked eye. This growth, or "colony," as it is called, which is made up of myriads of individual bacteria, the offspring of those planted, in many cases presents very characteristic ways of growing or special colors, etc., characters often by which particular species of bacteria may be distinguished from all others, even without the aid of the microscope. This gross appearance of the growing colonies is useful in the recognition of species which under the microscope look very much alike. Just as in agriculture, if one were in doubt as to two specimens of seed which closely resembled one another—say turnip and rape, for example—by sowing them in the ground and observing the resulting plants, all doubt would be removed.

In thus planting the invisible and minute bacteria, and allowing them to grow until such

large masses of colonies are formed that we can readily see and study them with the naked eye, we are realizing in another field a project which was urged with a good deal of persistency some years ago for finding out if there were inhabitants in the moon, and for communicating with them.

It was proposed to build in outline on some great plain on the earth's surface, like that of Siberia, a gigantic structure so large that, even assuming that the lunar inhabitants had no telescopes, it would be visible to them. This structure was to have some simple suggestive mathematical form like a circle or triangle. Seeing such a thing appear on the earth's surface, it was thought that the lunar inhabitants would probably "catch on"—this phrase was not known in those primitive times—and erect a similar structure, and thus communication would be established. The moon project fell through, but, as we have seen by a somewhat similar device, we actually make the inhabitants of an unseen world communicate to us to-day some of the secrets of their hidden life.

But the knowledge derived from the mode

of growth of bacteria on potatoes is limited, because as the potato is opaque we can see only the surface of the colony; and, furthermore, not all the bacteria grow well on potatoes, and some do not grow upon them at all. So the next step is to make some transparent solid substance which shall be a suitable soil for bacterial growth. One of the most common and useful substances for this end is a 10 per cent. solution of gelatin which is mixed with beef tea, pepton, and a little common salt, and then made neutral or slightly alkaline by carbonate of soda. This mixture, carefully heated so as to destroy all bacteria which might be present in its ingredients, is filled into ordinary glass test-tubes which have been sterilized by a high temperature. These are filled about one third full of the gelatin mixture, and the opening is stopped by a plug of cotton batting. Through a long plug of cotton, bacteria cannot pass; the air can enter and leave the tube, but all bacteria are caught by the fibres of the cotton. After the gelatin has become cool and solid, by means of a sterilized platinum wire, some of the bacteria are

introduced into the gelatin, the cotton plug being removed for an instant for this purpose. Being transparent, the gelatin permits us to see from the sides as well as from the surface the exact mode of growth of the particular form of bacteria introduced into the tube, and thus we learn a new set of characteristics for the different species (see Plate I).

But if we need to keep our bacteria at a higher temperature than that of an ordinary room, say at the temperature of the body, at which alone some forms will grow, the gelatin would melt and the bacteria would be scattered through it, and the characteristic mode of growth of the masses or colonies would be lost. So, for this purpose we use, instead of gelatin, agar-agar, a material derived from a sea-weed, which in 1 per cent. solution forms a gelatinous solid transparent mass, which may be heated to above the temperature of the body without fluidifying. To this are added, as to the gelatin, beef-tea, pepton, etc.

By the use of these various soils, or "culture media," as they are called, and many others

such as beef-tea, milk, blood-serum, etc., we can arrive at a series of characteristics in the mode of growth of various bacteria by which, together with their form when seen under the microscope, we can distinguish them one from the other, just as the naturalist distinguishes from each other nearly related animals and plants.

It is obviously of the greatest importance, as we have seen above, that we should be able to separate different species of bacteria from one another in the living condition, so that we may have growths or colonies which shall contain one species alone without admixture with any other. These are called "pure cultures." This is by no means an easy task, as will be appreciated when we consider how exceedingly minute the organisms are, and how much danger there is that the bacteria floating everywhere invisibly in the air may become mixed with those forms which we are studying. By a very simple device elaborated by Dr. Koch, of Berlin, we are, nevertheless, able at any time to separate one species from another with the utmost certainty, or from a mixture of

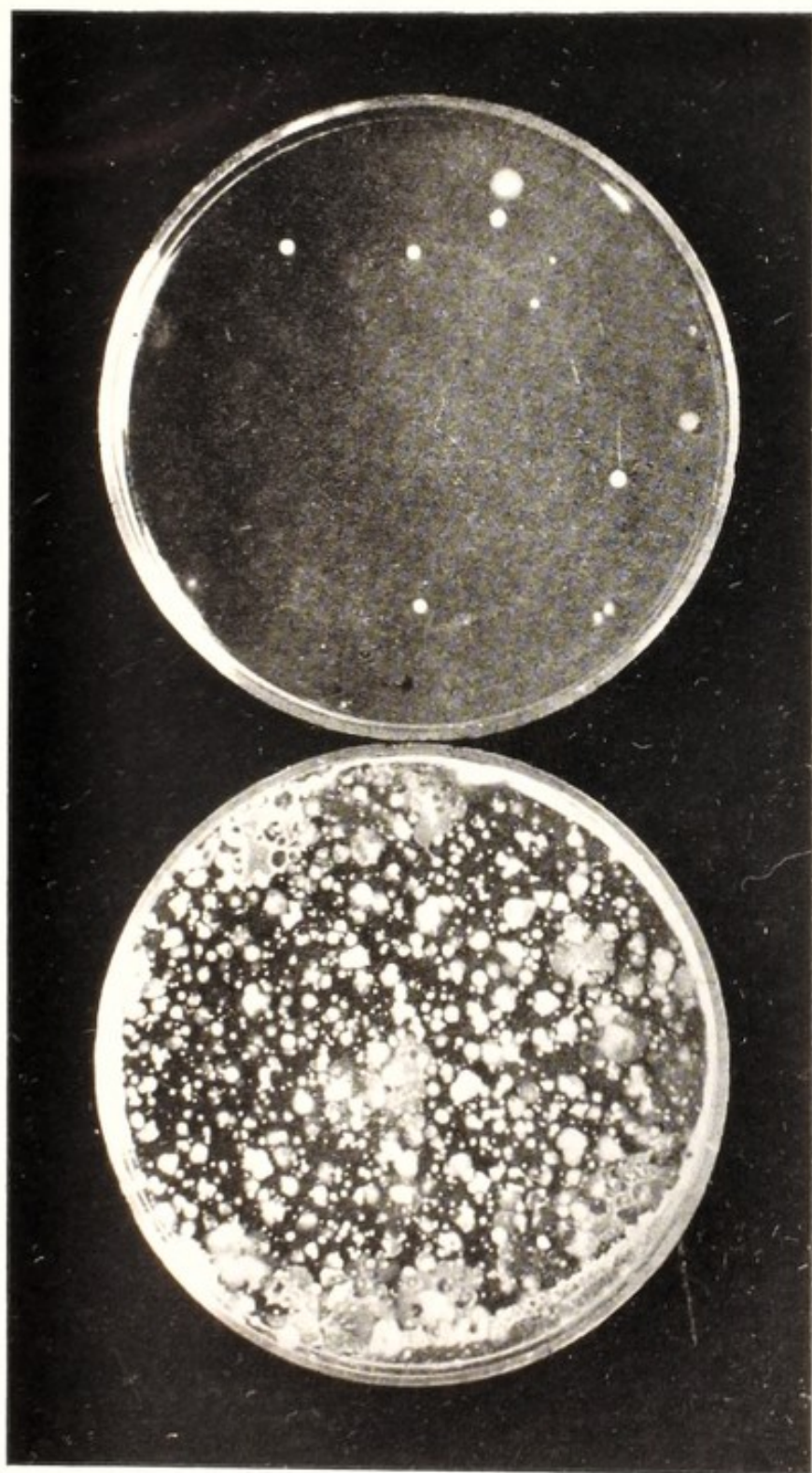


PLATE II.—PLATE CULTURES IN PETRI DISHES

The upper dish contains a few colonies, the lower shows many, of various sizes.



many species to get into separate tubes pure cultures of each species by itself. This is accomplished by what is called the "plate culture," the details of which are as follows: Suppose we have a mixture, say a sample of impure drinking water, which contains four different species of bacteria, which we wish to get into pure cultures in separate tubes.

We mix a small amount of the bacteria-containing water with a much larger amount of the above-described nutrient gelatin, melted by heat. Then we pour this mixture into a shallow glass dish with a glass cover, called a Petri dish, which has been carefully sterilized by heat, so as to form a thin layer. This soon cools and becomes solid. The Petri dish is covered to keep out any bacteria which may be floating in the air, and to prevent its drying, and is set away at the temperature of the living-room. The individual bacteria which were scattered through the gelatin layer will presently commence to grow.

After a few hours or days, as the case may be, if we look at the gelatin-film (see Plate III) we see, sometimes with the naked eye, some-

times only under the microscope, little points or masses scattered through the gelatin, which are colonies of bacteria, each one consisting of hundreds or thousands of the organisms which have grown from the single organism which was fixed at that point as by a solid wall when the gelatin cooled.

Of course, it sometimes happens that two or more of the original germs either of the same or different species were solidified in the gelatin when it cooled at the same place, and then the resulting colony will consist of all the organisms which have grown at this point, mixed together or growing closely side by side. In most cases, however, the little colonies are composed of the descendants of a single germ, and if we put the gelatin plate under the microscope we can see the different forms of the colonies which have grown from the different species. The differences in the mode of growth of the bacteria when planted and studied in this way are manifold: some are colored, red, green, yellow, orange, violet, brown, etc.; some are colorless, some have sharply defined smooth edges, some are jagged



PLATE III.—COLONIES OF BACTERIA

The larger of these colonies growing on gelatin in a Petri dish show fringed borders which are characteristic of the species.

or fringed—see Plate III; some are beaded, or send out little spines; some cause the gelatin in their immediate vicinity to liquefy, so that they come to lie in a little pool of fluid in a pit or depression in the solid gelatin.

Now, by examining the plate microscopically we can not only see how many different forms of colonies there are—and each different form of colony indicates a difference in the species of bacteria composing it,—but nothing is simpler than, directly under the microscope, to take out on the tip of a sterilized platinum wire little bits from each one of the different forms of colonies, and transfer them to separate tubes of gelatin. Thus we secure “pure cultures” of all the different forms of bacteria which were contained in the original mixture. Thus, minute as the individual bacteria are, lying far below the power of unaided vision, we are able to manipulate them with as much certainty as the agriculturist does his larger plants.

When we have thus got different species of bacteria separated from one another in the form of pure cultures, we can experiment on them in many ways, and learn their varying

characteristics. We can plant them under such conditions that their oxygen supply is limited, and learn whether they do or do not thrive; we can see whether they grow best at high or low temperatures, whether they form gas or not, and what degrees of heat or cold will kill them. We can grow them in large quantities, and study the chemical compounds which result from their life processes. We can apply to them various chemical substances which are called germicides, or disinfectants, and find out to which of these and in what strength they most readily succumb.

In this way a large number of different species of bacteria have been studied, and these have been arranged in groups which have some characters in common. So that already, although the study of the bacteria by the new methods is of recent date, we have the outline of analysis tables, something like those made for the identification of the higher plants in Gray's *Botany*, for instance, by the use of which the student can identify certain of the better known forms which he may come across in his studies.

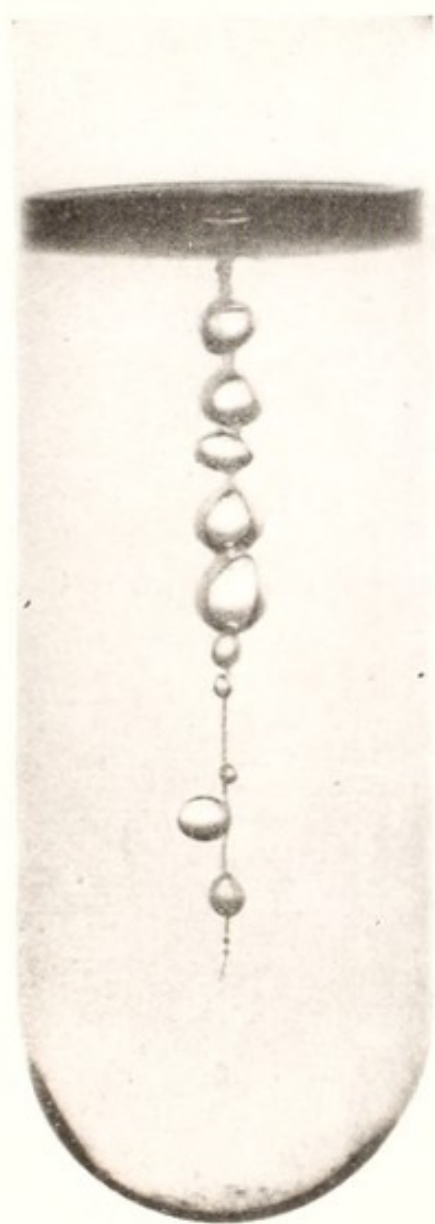


PLATE IV.—A BACTERIAL CULTURE SHOWING THE
FORMATION OF GAS

The cut shows the lower end of a tube of gelatin into which a needle was thrust on the tip of which were a few gas-forming bacteria. As these have grown along the puncture gas bubbles have collected.



The nomenclature in bacteriology is still in a rather chaotic condition, but a beginning has been made. The term *bacteria* (singular, bacterium) applies to the whole class of organisms of whatever shape. They are also sometimes called "germs," or "microbes," or "micro-organisms," which means small living beings. The round or spheroidal form is called "coccus," which means a berry; the plural is cocci. The botanical name of the most common form of the round or spheroidal bacteria is *Micrococcus*—that means "a little berry." Thus there is a species of micrococcus which produces a yellow color when it is growing in masses. This species is called *Micrococcus luteus*—the yellow micrococcus.

Another genus among the spheroidal bacteria is called *Streptococcus*—"a chain of berries"—Fig. 4—because the little balls tend to cling together and form longer and shorter



FIG. 4.—STREPTOCOCCI
FROM A CULTURE

chains as they grow. Another, growing in masses, is called Staphylococcus—"a bunch of berries"—Fig. 5. Then

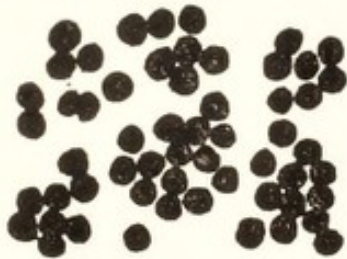


FIG. 5.—STAPHYLOCOCCUS FROM A CULTURE

among the rod-shaped bacteria the most common genus is called Bacillus (plural, bacilli), and some of the species of this genus are among the most common and abundant forms—Fig. 6.

Thus with a temporary and provisional system of classification, the work of studying and describing the bacteria is steadily going on. And if to see and describe living beings on which no human eye has ever rested before be satisfying, it will be long before the sighs of bacteriological Alexanders are heard in this unseen world, whose very shores have been barely touched by the new explorers.



FIG. 6.—BACILLI FROM A CULTURE



CHAPTER IV

SOME BACTERIAL CURIOSITIES

MOST travellers, and some people who stay at home, too, have now and then been mystified and delighted, when not frightened, to see in the night-time that wavering, cold, uncanny, but beautiful light, sometimes tinged with the most exquisite green or blue, which is commonly called phosphorescence. Sometimes it is seen in decaying plants or wood; sometimes bays or inlets of the sea are fairly luminous with it. The surface of dead fish and of meat and various kinds of vegetables often becomes so bright as to illuminate the storage rooms in which they lie.

Some time since there was brought to the laboratory for examination a cluster of sausages which had been destined to grace a

boarding-house breakfast-table. To the consternation of the maid who went into the dark cellar for them in the early morning, there hung in the place of the sausages a fiery effigy which seemed to her more like the quondam spirits of their mysterious ingredients than the unctuous homely friend of the homeless boarder.

The explanation of this is now simple enough without recourse to the supernatural; for it has been recently shown that this curious light which various organic substances emit is due, in many cases at least, to the enormous numbers of certain kinds of bacteria which are present on their surfaces, hard at work feeding on the organic compounds which are present and undergoing decay. Pure cultures of these singular bacteria have been made and cultivated in considerable quantities. These bacterial masses, together with the tubes in which they were growing, have been placed in a dark room with an open watch beside them, and bacterial masses, tubes, and all actually photographed by their own light, the pointers of the watch

showing distinctly the time of day. So it would seem that this cousin of the will-o'-the-wisp—no doubt often mistaken for him—is no malevolent genius after all, but a quiet little citizen working away as diligently as he can to make the world more comfortable for his betters.

It has long been known by the makers of beverages that alcohol is formed in certain sugary mixtures by a process called fermentation, and that this tearing to pieces of the sugar into other compounds, one of which is alcohol, is accomplished by a little living organism called yeast, closely related to the bacteria. In the earlier days of beer- and wine-making it was often found that the beer did not work or ferment properly, and that wine would get sour or bitter. We now know that these irregularities are due to the fact that certain kinds of bacteria are apt to get into the wine or beer during the manufacture, and when they do a bitter struggle for food goes on between the yeasts and the bacteria; or the latter may bide their time, and later in the process begin to grow and produce

very undesirable compounds in the fluids. So the manufacturer has to be on the alert, and at the right moment come to the rescue of his army of servitors, the yeast plants, and introduce into his beer some chemical substance which is innocuous to them but deadly to the intruding bacteria. Or he may raise his wine at a certain period to such a temperature as will suffice to kill the bacteria but not injure the flavor of the already fermented juice. Here again as in the case of the farmer we see the bacteria coming into conflict with the purposes of their earth-neighbor—man.

Some of the bacteria are great lovers of oxygen, and if they are shut up in a little cell containing a few drops of water in which a bubble of air has been enclosed, after a while it will be found that those forms which are capable of locomotion have made their way from all parts of the fluid, which is a veritable ocean to them, and are closely clustered around the air bubble, jostling and bumping against one another in the most reckless way. It seems almost as if this rush towards the

oxygen were an evidence of volition in its simplest form way down on the lowest border-line of life.

Some forms of bacteria are exceedingly invulnerable to the action of cold, and can not only move actively about in very cold water, but can remain alive for long periods fast frozen in a mass of ice. Now a very curious thing has been noticed in the ice which is gathered in these regions and which we use for domestic purposes, and that is, that the so-called bubbly streaks which we usually see in our ice blocks contain, as a rule, many more bacteria than does the transparent ice close by.

It has been found, on cultivating the bacteria from the bubbly streaks, that the species which was most abundant here is an oxygen lover, and is also very mobile. Now the bubbles which collect in streaks or layers in the ice collect during the daytime, or when the ice is not freezing very fast below, and there is time for the air-seeking bacteria to gather around them in great numbers. But now, when a clear night or a cold snap comes

on, the ice closes around both bubbles and bacteria, and we have formed, to use the language of the geologist, an air and fossil-bearing stratum. Only our bacterial fossils are not dead, and all we have to do in order to find out what forms of life were present in our successive geological periods, limited perhaps only by a night, is to melt a bit of the ice, mix it with our culture gelatin, and in a day or two we shall have a whole garden of growing plants, which we can study at our leisure.

But many bacteria can survive a temperature much below freezing. Experiments with liquid air, which affords extreme degrees of cold, have shown that exposure to more than 190° C. below zero leaves some bacteria quite unharmed. While many bacteria thus survive extreme cold, they do not multiply at low temperatures, so that the use of ice in preserving foods is of great importance.

On the other hand, there are bacterial species which prefer high temperatures. Thus some forms flourish in the water of hot springs at a temperature of 170° Fahrenheit. These are called *thermophylic* or "heat lovers."

As a rule, bacteria are soon killed by bright sunlight, and even in diffuse daylight many pine and die.

Among the most curious things which the bacteriologist has to exhibit in his bacterial conservatory is the color-forming species. It is only when they are growing in masses, of course, that enough color is formed to be visible; but then one may see in the little slimy masses which cover the surface of the food or culture media in the tubes, every color of the rainbow and many variations in hue. Sometimes not only is the bacterial mass itself brilliantly colored, but some of the chemical substances which they form as they grow permeate the gelatin and give it a beautiful fluorescence, green or red.

The writer was not long ago standing beside a supper-table, whose sole floral decoration was a bunch of large, exquisitely tinted chrysanthemums, when a friend remarked upon the patience and skill which had been required to develop this magnificent flower by artificial selection from its simple and homely ancestor, and queried in a quizzing

way how long it would be before somebody would be trying to modify the colors of some of the bacteria by the well-known horticultural methods. His idea was a clever one, but he was behind the times, for already a German bacteriologist had, starting with a deep purple-forming species of bacteria, and selecting and replanting the lighter-colored colonies, at last obtained cultures which were nearly white, but were in other respects essentially the same.

In many other ways the bacteriologist can modify the life processes of bacteria by successive generations of selective cultures. Acid producers can be restrained, or their powers exalted. Lovers of oxygen can be made to go without it. The fermentative and putrefactive capacities of many forms can be profoundly altered. They can be adapted to strange foods and to outlandish conditions. Harmful species can be rendered harmless and the virulence of other forms exalted.

Thus the great and far-reaching principles of natural selection, in accordance with

which life, slowly emerging from its primeval simplicity, at last came to be manifested in that grand scale of living beings at the top of which man stands supreme, are still to be traced way down among the invisible organisms which typify the earliest and simplest expression of life.

But certain of these color-forming bacteria are sometimes very disagreeable intruders upon domestic life. Occasionally, without warning, the milk of a particular dairy suddenly develops a very uncanny deep-blue color, which, like an epidemic, spreads to all the milk which is stored in special rooms. This occurrence, for a long time a disagreeable and costly mystery, is now known to be due to a tiny bacterium of the genus *Bacillus*, which, floating about in the air with the dust, from time to time infests rooms, and, falling into the milk, grows there, producing the blue coloring matter.

Sometimes milk gets red instead of blue, and then the change is due to another form of bacteria floating with the dust. Bread, too, may become infested in the same way,

and the dough set aside in bake-shops overnight to rise has not infrequently been found in the morning resplendent with colors which fairly rivalled those of the rising sun.

There is a species of bacteria in every good collection, and a veritable Nestor among the forms known to man, which has a curious ecclesiastical history. Among all the innumerable natural phenomena which, by their striking character, infrequent occurrence, and lack of apparent cause, were in early times relegated to the domain of the supernatural, none perhaps was more strange and uncanny than the sudden appearance on the moist surfaces of articles of food of little bright-red shiny droplets, which, gradually spreading, at length formed large shiny, deep, rich-red masses, looking very like drops, or masses, or clots of blood. The story is long and tragic of the dire calamities, unmentionable crimes, and swift retributions which these strange appearances of blood were supposed to foreshadow.

This miracle of the bleeding Host has appeared again and again in the hands of the

priestly defenders of the faith as a most potent evidence of divine intervention with the affairs of men. The consecrated wafer placed overnight in the moist and bacteria-laden air of the church edifice, would in the morning be found besprinkled with bright-red drops. What could it be but blood? No human hand could have come near the place, and so what else could be believed but that it was from the hand of God? It was one of those early miracles in which both priest and layman could alike share in believing with perfect honesty. The divine finger pointed, but to what, it was the office of the priest to say. How many lives were sacrificed and homes destroyed through that most honest of ecclesiastical delusions, the miracle of the bleeding Host, it were useless now even to conjecture.

To-day we cultivate in our tubes the tiny bacteria which, growing in masses, made the drops of blood, and the last elements of romance and tragedy seem to disappear from the story as we name them—*Bacillus prodigiosus*.

There are some species of bacteria which are mortal enemies and cannot live together, one species killing out the other almost as soon as they come in contact. The details of this invisible mimic warfare we do not yet understand, nor do we know what are the weapons with which it is carried on. It is probable that it is in virtue of some poison which they form as they live and grow that the victors gain possession of the field.

On the other hand, there are two or three instances of a sort of one-sided Damon-and-Pythias story among these creatures; for in the attempts to isolate the species by culture it has been found that sometimes two species can be isolated and grow together, but if the attempt be made to separate them, one of them always dies. The exact nature of this friendly tie is still unknown. Perhaps in this case the material which is set free by one species as it feeds and grows is the only thing upon which its associate can live and thrive.



CHAPTER V

AGRICULTURAL CONJURERS

LIVING bodies are made up largely of oxygen, hydrogen, carbon, and nitrogen. While these are all very abundant in the world, nitrogen seems to be about the most difficult for both animals and the higher plants to get hold of, because in the ordinary form in which it exists in the atmosphere it is not directly available. Man and his relatives, the meat-eating animals, get nitrogen mostly from other animals or from plants, and ultimately the nitrogen, which animals require, comes from plants. The higher plants get their nitrogen largely from certain chemical compounds in the soil called nitrates, which the bacteria have been active in forming out of the dead stuff of former living things.

Give the farmer soil, water, air, sunshine,

and seed, and his task is to get a crop. This seems simple enough. In fact he has oxygen, hydrogen, and carbon a plenty. The trouble is with the nitrogen, which is so abundant that it makes up about four fifths of the volume of the air. But plants can't eat pure nitrogen. So the farmer has to secure it in a roundabout way. As all animal and vegetable substances contain nitrogen, and, when dead and decaying under the influence of bacteria, give up those nitrogen compounds which living and growing plants require, he gets this dead stuff wherever he can. His great domestic supply is from his barnyard manure. This is in truth the most valuable product of his farm, if he knows how to care for and use it. But he often spends a great deal of money in buying imported nitrogen in the form of Chile saltpetre or other compounds. There are commercial laboratories which prepare artificial nitrogen compounds for the farmer. But for all these things he has to pay out his hard-earned cash.

Some crops, notably grain, take a great deal of nitrogen out of the soil, so that if a



PLATE V.—NODULES ON CLOVER ROOTS

new supply be not furnished, after a while the land becomes impoverished. This is one reason why there are in some parts of the country so many abandoned farms—too little nitrogen—and the atmosphere full of it.

It has long been clear that if the farmer could only directly tap the atmospheric nitrogen, his fortune would be made. It has been known ever since the times of the old Romans that what is called "green manuring," that is the ploughing under of crops of leguminous plants, such as clover, enriches the soil in quite a remarkable though mysterious way. But the reason for this common practice was left for the modern bacteriologist to discover. And here enters one of the most noteworthy of the bacterial conjurers.

Farmers and other students of plants for a long time have been familiar with certain little nodules or tubercles (Plate V.) growing on the roots of leguminous plants such as clover, peas, beans, etc., and had supposed that they indicated some kind of disease of the plant. But a few years ago it was dis-

covered that these root nodules are made up largely of rod-like and irregular-shaped bacteria (Fig. 7). Several forms of these can now be cultivated artificially, and it has been found that they have the power of seizing upon atmospheric nitrogen and working it



FIG. 7.—NODULE BACTERIA

These irregular shaped bacteria were artificially cultivated from the nodules on the roots of leguminous plants.

over into available form for the uses of their host. These bacteria get into the rootlets of the leguminous plant and grow there as parasites, not at first altogether welcomed it would seem. But presently they begin to satisfy the intense nitrogen hunger of the clover, alfalfa, peas, and beans, and thus the happy family lives on in mutual helpfulness.

So at last, down in this borderland of life has been discovered the key to untold riches for the farmer. For he now knows the importance of root nodules and their bacteria, and can transfer them from field to field, or he can get from

the Federal Government, or from State agricultural or other laboratories, artificial living cultures of these wonder working germs with which he may inoculate his field. Then he may leave them in the rootlets of his crops to conjure from the air, by day and by night, this precious atmospheric nitrogen. This the higher plant will thrive upon and thriftily store away for the future uses of man and beast.

There are certain other bacteria in the ground which can fix the atmospheric nitrogen as they grow and so enrich the soil. In this way fields, which have plenty of vegetable mould, may improve when allowed to go fallow for a time. But the various forms of nodule bacteria which join forces with the peas and beans and clovers in turning air into gold are the more dramatic conjurers which modern science has presented to the farmer. You will find plenty of pictures in the books which deal with scientific agriculture, showing lean beans with their noduleless roots beside others, the nodular and leafy opulence of which betokens their silent partnership with the atmosphere.



CHAPTER VI

BACTERIA AS MAN'S INVISIBLE FOES

WE have seen that the bacteria in general are not only curious and interesting as objects of study, but in the work which they are ceaselessly and silently doing they are absolutely indispensable to the continuance of the higher forms of life upon the earth. But unfortunately there is another darker side to the picture. Among the myriads of useful as well as harmless bacteria, we have lately learned that there are a few forms which find the most favorable conditions for their life and growth in the bodies of men and some of the higher animals.

Most of these do not grow well in nature as other bacteria do, nor do they thrive on ordinary decomposing organic matter. They look very much like the more common

harmless bacteria, some being little balls, some rods, and some spirals. Like other bacteria, they grow at the expense of the materials with which, under favorable conditions, they come in contact, and like them they produce new chemical compounds as the result of their life processes. When they get into the human body, the different species grow in different ways, and produce different kinds of chemical compounds, and this growth or the poisonous substances which are formed induce disease.

Bacteria which can grow in the body and do serious harm there are called *pathogenic* or *disease-inducing* bacteria. The poisonous chemical compounds which they set free as they grow, are called toxins.

Now, before we try to comprehend how disease can be induced by bacteria, we ought to understand what disease is.

We have seen in the first chapter that the human body is made up of several communities of cells, each community having acquired the power of doing some special thing for the good of the body as a whole, and that

these cell communities are all co-ordinated so as to act in harmony. We have seen that these cell communities which make up this wonderful mechanism are all originally derived from a single living cell, the ovum.

What this mysterious thing is which we call life, which from the original cell, the ovum, is imparted to all the myriad specialized cells which springs from it as the body grows; what it is which determines that from one of two cells which under the most powerful of microscopes look exactly alike there shall develop a man, and from the other an animal, we simply do not know. We theorize, we speculate, we draw analogies, we give names, but at the end we conclude that we must wait still for more light. We do know, however, that this self-built cellular mechanism, the body, which is alive, has in it the power of self-renewal: the power, when once started, to go on doing the various things for which it is fitted for a time, provided the proper external and internal conditions are maintained. But sooner or later the machinery begins to creak and tremble, sometimes in one part, sometimes

in another, sometimes everywhere, and gradually or suddenly that combination of activities which we call life disappears, and the worn-out mechanism for the first time since it came into being is still. This is death. There is no disease, but, as we are apt to say—not because it means much, but because we think we must say something,—an exhaustion of the vital forces. The mechanism is worn out, and so can no longer develop out of food and air the self-renewed impelling force. It is death from old age. But this is comparatively infrequent.

If the proper food, air, and surroundings are maintained, the various co-ordinated cell communities which we call liver, brain, kidneys, lungs, integument, and so forth, provided they are properly set going in the first place, have not only the power to go on doing their work, but they have a well marked capacity for overcoming and resisting deleterious agencies of one kind and another,—a sort of health inertia. The muscle cells do make shift to contract even though their food supply be temporarily scanty; the blood

cells will carry a certain amount of oxygen in their ceaseless rounds of visits to the tissues, though the air from which they get it through the lungs be as foul and meagre as it is in some of our fashionable theatres and churches and school-rooms. And if certain cells or groups of cells should be forced to work awry, they always tend to get back to their proper business and conditions, even against great obstacles, just as soon as they can.

Even when large numbers of cells or cell groups are entirely removed from the community, as by an injury, new cells can form out of those which are left, or the duties of the lost cells are assumed and may be permanently maintained by their fellows. Patriotism and *esprit du corps* are very markedly typified in the cell communities which together constitute the republic or commonwealth called the body.

When important cell communities are seriously injured or changed in structure so that they cannot do well the things which they ought to do, or when they fail to act in harmony, through some fault of their own or some

disorder in the co-ordinating mechanism, the failure in what we may term the rhythm of the body's activities constitutes what we call disease.

The part which may be the seat of the disease is as varied as are the organs and tissues of which the body is composed.

The disturbances in the activities of the body which result from these changes in the structure and action of the various parts have been so long studied that the educated physician is usually able to tell from certain irregularities of the body's activities what part or parts it is which are affected. In many cases the physician does, in some he does not, know what is the exact cause of the disturbance. In some cases, when the cause of the disturbance is known, he can remove it either by directing a change in the habits or by the administration of drugs, and then the tendency of the cell communities of the body to get back into their proper condition of themselves alone will restore health. Sometimes this inherent tendency is aided by the use of medicines. Most of the body's disturbances

tend to pass away of themselves after a longer or shorter period, if they are not so severe as to destroy life. Under these conditions the duty of the physician may be only to aid the body by food and air and proper regimen in the work which it is doing itself. And so through the long list of ills which come upon the human frame from known or unknown causes the wise physician guides and aids the natural recuperative tendencies of the body cells.

Among all the varied changes in structure and disturbance in activities of the body which thus constitute disease there are, as we have seen, several, and these most important ones, which have recently been proven to be caused by bacteria. To some of these we must now turn our attention so as to learn how the disturbances are brought about, and what we may do for ourselves to avoid them.

But before we enter the domain of the doctors, let us devote a moment to their shibboleths, by which it may be known whether we are of the elect or only dabblers.

A disease which is incited by the entrance

into the body and proliferation there of pathogenic micro-organisms is called an *infectious disease*; the organisms, the infective agents. These organisms are most frequently bacteria, but other minute plants, such as yeasts and animals called protozoa, are sometimes to blame.

Each infectious disease has its special features by which the doctor knows it. These features depend upon the species of the invading germ, its way of growing, the poison it sets free, the length of its life span. But the body cells have their particular vulnerabilities to microbic invasion and poisons. So that in one case it is the nervous system, in another the lungs or the blood or the digestive system which especially suffers. Moreover, as one rose is redder than another, or one aromatic plant more pungent than its fellow, so in one case the germs which gain access to the body may involve a more potent poison than do those of the same species but of another strain, and then the disease may be more virulent in type. So also an individual may at the time of in-

fection be more susceptible than is usual to the ravages of the invader and thus be the victim of a graver form of the disease.

Infectious diseases of the type of small-pox, measles, and scarlatina, whose infective agents are easily transmitted, are called *contagious*. When it is said of an infective disease that it is more or less readily *communicable*, it is really meant that the infective agent is communicable, not the disease. For disease is always a process of the body and not a thing, and so cannot be transmitted.

The elder folk were wont to think of diseases as some sort of demons or evil spirits which attacked the body or took possession of it, and tried to banish these by rattles, drums, or songs and incantations, as some of our North American Indians do to-day. Though we know that disease is not a thing but a disturbance of the body processes, we still speak of disease as attacking the body. We say "the man was attacked by a severe dyspepsia after eating hot plum pudding." But it was really not the dyspepsia, it was the plum pudding which attacked the man.

Dyspepsia, the disease, was only the process of reaction or defence against the pudding.

So if we choose to be dramatic in our speech we may still say that disease attacks a man. But let us hold it in the back of our heads, that we do not really blame the disease but the bacteria or other factors which have set it going.

It is well to do this, not only for the sake of clearness of conception, but because when we try to cure or prevent disease, it is the inciting factors which we must strive to control, and not only, or chiefly, the symptoms, which characterize but do not constitute the disease. For in a large proportion of cases the symptoms of disease are only the marks of the efforts of the body to protect itself against some offending condition or invading thing. Fever and pain, cough and headache, the halting appetite and laboring heart—these may all be only signs of wholesome resistance to damage, or warnings against improper or unsafe modes of life.



CHAPTER VII

THE BACTERIA OF WOUNDS AND OF SURGICAL DISEASES

ONE of the greatest dangers associated with injuries and wounds of the body, whether inflicted by accident or made by the knife of the surgeon in necessary operations, is the liability to what is known as blood poisoning.

So great is this danger, that in earlier wars a great many more lives were usually lost from blood poisoning than by bullets or cannon-balls. The cause of this form of disease, which is so apt to complicate wounds, was for a long time unknown. Then, as these wounds were apt, in blood poisoning, to be foul and bad-smelling, it was concluded that the trouble might be that dirt or filth

of some sort got into them and so set up the disease.

What the particular thing was, whether bacteria or something else, which so gained entrance to the body, no one knew. But the surgeons did not wait until they should know all about the cause of the trouble, but began to apply to the wounds such materials as would actually kill germs, or, at any rate, keep the wounds free from putrefactive changes. Carbolic acid, dissolved in water, was found to be efficient in this way in washing the wounds.

Then, as it seemed more and more as if the trouble were due to living germs falling upon the wounds from the air with the dust, it became the practice, when surgical operations were being done or wounds dressed, to spray carbolic in the air about the operator's hands and over his instruments and upon the wounds, and when the bandages were put on to seal them in tightly, so that no germs could gain access to the wound while the healing went on. All this time the particular species of bacteria which produced the trouble remained

entirely unknown; indeed, it was only an hypothesis that the disease was due to germs at all.

A great deal of careful laboratory work has, however, been done on this subject, and a great many animal experiments made, so that



FIG. 8.—STREPTOCOCCUS PYOGENES

now we know not only that blood poisoning but boils, abscesses, erysipelas, and many other less serious inflammations are induced by bacteria. We have found out, furthermore, that there are two particular species

which cause the trouble in the great majority of cases.

Both of these bacteria are little balls or micrococci. One of them, as it grows, tends to form chains, and so is called Streptococcus (Fig. 8); the other tends to group itself in clusters a little like a bunch of grapes, and so is called Staphylococcus (Fig. 9).

Now, it has been further found that these two forms of bacteria are quite abundant where people are gathered, mostly in dirty

places; sometimes where the healthy, but especially where sick people are crowded together, as in hospitals. They are found in small numbers floating with the dust in the air, where dust lodges, and often in the mouths and on the clothing of the people themselves.

It is thus evident how the wound diseases, such as blood poisoning, can come about, for wherever infective dust falls on the open surfaces of the wounds or on any thing which comes in contact with them, or if the hands of surgeons or others who dress wounds are not free from the dangerous bacteria these may, if not destroyed, commence to grow, and not only by the poisonous materials which they form as they grow, interfere with the healing of the wounds, but they may get into the blood and be carried to various parts of the body, there sometimes producing fatal results.

The modern surgeon, in the many beneficent



FIG. 9.—STAPHYLOCOCCUS PYOGENES

operations which he performs, is not so much concerned about the bacteria which may fall upon the wounds from the air, as he is about those germs which may be upon the hands or face, or may come from the mouth or nose or from some insignificant pustule or a boil of himself or the attendants, because these are more apt to be fully virulent than are bacteria which have been dried and sunburned in the dust. So he does not use disinfectants as much as was formerly the case, but sees to it that the seat of operation in the patient, and the hands of the attendants and all instruments, towels, bandages, etc., which may touch the wounds, are freed beforehand, as nearly as possible, from all contaminating germs.

This is the aseptic, which has supplanted the antiseptic surgery. The aim is to keep bacteria out of wounds, rather than to try to kill them with antiseptics, after they have been allowed to get in. Clean white aprons, caps and gowns, rubber gloves, or fresh scrubbed hands, sterile instruments and dressings—these are the insignia of aseptic surgery, whose watchword is cleanliness.

It is one of the greatest practical triumphs of science in modern times that the surgeon can now so carefully plan out his operations and treatment of wounds, that not only is blood poisoning, as it used to prevail but a few years ago, the greatest rarity among educated and skilful surgeons, but the most extensive operations, such as opening the great cavities of the body, may now be done, when they are necessary to save life or make it endurable, with very little risk of the dangers which formerly attended such procedures.

Childbed fever, which in former times claimed so many victims under especially pitiful circumstances, and which used sometimes to spread with frightful rapidity among women whose confinement took place in hospitals, is now of comparatively rare occurrence, because the educated physician knows what the particular element of danger is and how to avoid and combat it. For it has been found that childbed fever is really a form of blood poisoning, due to the same germs as induce the disease in ordinary wounds.

Dr. Oliver Wendell Holmes, early in his

career, became convinced that the poison causing childbed fever could be carried on the clothes of the physician from one patient to another. What the poison was he could not even fairly conjecture, but of the fact he was certain. In spite of much opposition and ridicule he urged his views, and many lives were ultimately saved and epidemics stayed because of his persistency in making known his facts. To-day we not only know that all that he urged was true, but the poison which he assumed but could not see has been proved to be bacteria, and we can now cultivate them in tubes and know exactly what will most surely destroy them. While literature owes much to the wit and cleverness of the genius of the breakfast-table, science and humanity are not less debtors to the zeal and pertinacity of the young doctor, who still declared for his beliefs, though his more aged and then more renowned confrères applied to him many terms of opprobrium and disrespect.

Now let us look a little more closely at the way in which these tiny organisms induce inflammation, suppuration, or the formation

of pus and blood poisoning. We have seen in the first chapter that although most of the cells of the body have assumed special forms and powers as the body develops out of its embryonic period, there are some cells which scarcely seem to have got beyond the stage in which the simplest of the unicellular organisms, such as the amoeba, belong. The most prominent of these lowly organized cells in the body are the white blood-cells or, *leucocytes* as they are called. (See Plate XI.) Under ordinary conditions these go circling round in the blood-vessels along with the red blood-cells, or, crawling out of the blood-vessels, slowly make their way about in the smaller spaces in the tissues. All the things they do under these circumstances we do not know. But they are at any rate the great scavengers of the body. When they come across a particle of worn-out or foreign material in the tissues, they take it into themselves, just as amoeba does its food in water, and either digest it or carry it back to those parts of the body in which waste material is systematically disposed of.

But let an injury such as an open wound occur, and the whole attitude of these leucocytes changes. They get out of the blood-vessels with all speed, in greater or less numbers as the occasion may demand, and gather about the edges of the wound, and after a time they, together with some other cells of the injured tissue, form, with the aid of the blood-vessels near by, a mass of new tissues, which replaces that which was lost by the injury, and so permanently binds the edges of the wound together. Sometimes these white blood-cells gather in much greater quantities about the wound than is necessary, and then they are thrown off with some fluid in the form of a material which we call pus.

Now to come back to the bacteria which we are studying. When these bacteria get into the tissues, they may begin to grow, and as they do so they produce a small amount of a poison which we call a toxine. This poison acting injuriously on the tissues where it is formed, the white blood-cells gather about it just as they would about a wound. If the bacteria continue to grow and multiply, the

white blood-cells may accumulate more and more and die, the tissues may break down, and so an abscess may be formed. Sometimes the germs get into the blood and are carried to various parts of the body, and wherever they lodge abscesses may be formed, and this constitutes one of the most dreaded forms of blood poisoning.

Now what do the white blood-cells, the leucocytes, accomplish under these circumstances?

There is good reason to believe that the resisting capacity of the body to the incursions of these living bacteria is largely resident in the lowly organized cells, which in carrying on their simple cellular activities assume the rôle of defenders of the body against the bacterial invaders. If the conditions are favorable for them the white blood- and other cells may get the upper hand of the bacteria and stop their growth or kill them all off and thus avert the danger. If, on the other hand, the cells are not vigorous enough to resist the poison set free by the bacteria and themselves succumb to its influence, the

way is opened to the spread of the infecting germs.

In a later chapter on the safeguards of the body we shall look a little more closely at this significant battle of the cells in various infectious diseases.

It sometimes happens that so extensive a growth of the bacteria occurs in some local region of the body and so much of the soluble poison is produced that although the bacteria may not themselves get generally distributed the poison which they furnish may enter the circulation, and so produce in distant parts of the body most serious disturbance or even cause death. The condition in which bacterial poisons are circulating in the blood is called *toxæmia*. When the bacteria themselves escape from their primary seat of growth and with their toxins gain access to the blood the condition is called *septicæmia* or *bacteriæmia*.

These bacteria of suppuration apparently do no harm when they lodge upon the uninjured surface of the body, but only when they get into the tissues through an injury

or lodge upon surfaces of the respiratory or digestive tract or in the heart and blood-vessels which are already the seat of disease. When they get into the hair follicles of the skin, however, under certain conditions they may incite boils.

This is in brief the story of the bacteria which most frequently induce the common inflammations of the tissues, the complications in the healing of wounds, and the varying phases of blood poisoning.

As pus in greater or less quantity is apt to be produced under these circumstances, these bacteria are called the pus-forming or *pyogenic* bacteria so they are named *Staphylococcus pyogenes* and *Streptococcus pyogenes*. (See Figs. 8 and 9.)

Some other bacteria may occasionally induce similar disorders in the body, but those which have been described are the most common and important.

In addition to their power of inciting inflammation alone or together, the staphylococcus and the streptococcus are so common among city folks and those who live crowded

together, that they are frequently present in other bacterial diseases which they may seriously complicate.

The effects which the pyogenic as well as other disease-inducing bacteria may produce in the body vary considerably under different conditions. Sometimes the general state of the body is such that it seems to furnish very favorable soil for their proliferation or is especially vulnerable to their action. Sometimes the particular germs which gain access seem to be especially virulent, perhaps from their inherent vigor or from conditions which we know nothing about. We are in these diseases dealing with poisons for the human body, but with self-propagating poisons which from an almost infinitesimal amount may grow to such quantities as in the end can fairly overwhelm it.

The habits of scrupulous cleanliness afford our best protection against the intrusions of these germs. In vigorous general health lies our strongest resistance to their incursions.



CHAPTER VIII

THE BACTERIA OF CONSUMPTION, OR TUBERCULOSIS

MORE than one seventh of all the people who die are carried off prematurely by consumption, or tuberculosis. But it is only recently that we have had any definite knowledge as to its cause. For a great while physicians have known a great deal about the disease. They have become very expert in detecting its advent and in tracing its course, and came long ago to know but too well whither it tended. It was usually regarded as hopeless, and its treatment was entered into rather for humanity's sake than in the expectation of inducing a cure. To-day the aspect of affairs has greatly altered. We know through the illuminating discoveries of Koch that tuberculosis is caused, and

caused alone, by exceedingly minute, rod-shaped bacteria—bacilli—which, in one way or another, gain access to the body (Fig. 10). When there, if the conditions are favorable, they tend to grow, and as they do so there



FIG. 10.—TUBERCLE
BACILLI

From the sputum of a person having tuberculosis of the lungs.

form about them little masses of new tissue, which are called tubercles. The most common seat of the disease is the lungs, but it may occur in any part of the body.

The tubercles which form in the lungs are usually limited to a small area, often at the top of the chest. But sometimes they are widely scattered through the lung. Plate VI. shows numerous tubercles—the little white spots—in a human lung.

Where the tubercles form the tiny air chambers are destroyed and the lung becomes solid. This is shown in Plate VII. The dark mass just beneath the surface of the lung is the tubercle. Around it are the air chambers quite open and useful.

But after a while, the poisons of the tubercle bacilli destroy these new-formed tubercles as well as the lung itself and then they often become friable and break down. Thus cavities of considerable size may form in the lungs. Plate VIII. shows a series of such cavities.

On the walls of these cavities the tubercle bacilli often grow in enormous numbers and as the cavities usually connect with the bronchial tubes, the bacilli may be cast out in the sputum.

We know that tuberculosis is never caused by any other thing than the tubercle bacillus, and that even in persons predisposed by inheritance or otherwise to the disease it cannot occur unless this particular germ gets into the body from outside. The germ itself has rarely, if ever, been shown to be directly inherited. If, therefore, we could keep this particular germ away from human beings, there would be no more tuberculosis, no matter what the inherent tendencies of the individual might be.

In fact, human beings in general are very resistant to the incursions of the tubercle

bacillus. This is shown by the fact that physicians, making autopsies upon the bodies of large numbers of persons who have died from accidents or diseases other than tuberculosis, have found that nearly every adult has at some time in his life had some small focus of tuberculosis. This his body cells have so successfully and promptly controlled that he has been wholly unaware of the infection. But while this shows the resisting capacity of human beings to the tubercle bacillus, it also indicates the wide distribution of the bacillus in the places which man frequents.

When an individual recovers from tuberculosis, the bacteria are destroyed and the new growth which is called the tubercle is slowly converted into dense tissue like a scar. Sometimes the body cells build a wall of scar tissue around the bacilli and the affected region (Plate VII.), so that the tuberculous process may lie dormant for a long time.

Now where do tubercle bacilli come from? Remember that they do not grow outside the bodies of warm blooded animals, except



PLATE VI.—TUBERCLES IN THE LUNG

In this case myriads of tubercles about the size of a grain of millet are scattered through the lung. This form of the disease is therefore called "miliary tuberculosis."

in the artificial cultures of the bacteriologist (see Plate IX.). So we need not look to sewage, polluted water, or dirty vegetables, or rotting stuff of any kind as fruitful sources of distribution. It is in tuberculous human beings and tuberculous cattle that we find the great sources of infection.

Let us look first at the human source. The masses of new tissue which form in the lungs where tubercle bacilli grow are not well supplied with blood, and so under the influence of the poisons which the bacilli set free as they grow and flourish and die they are apt to become friable and break down and then little particles of them containing myriads of living virulent germs are coughed up and discharged in the sputum. So the sputum of persons with tuberculosis of the lungs and the secretions in their mouths and sometimes the nose and their lips often swarming with bacilli are the immediate sources of distribution of these sinister germs.

Now, if the material which consumptive persons cough up and spit out were always destroyed at once by being burned or received

into a dish of some efficient disinfectant, one of the greatest dangers of the spread of the disease would be removed. But unfortunately this is in fact very rarely done. Thousands of consumptives are walking about the streets of our large towns or visiting places of assembly, who discharge the infectious material coughed up from the lungs upon the pavements or floors. This dries, and shortly is ground up, and takes its place among the rest of the floating dust of the air.

Essentially the same thing takes place in rooms in which consumptives are confined, if intelligent precautions are not taken to destroy or convey away the discharged material. It has been found by actual experiment that a considerable number of living tubercle bacilli may be lodged, together with other dust particles, high up on the walls of hospital wards in which consumptives are unintelligently cared for, in situations to which they could have been conveyed only through the air as ordinary dust is. The same material allowed to dry on handkerchiefs may in a similar way become a source of danger,

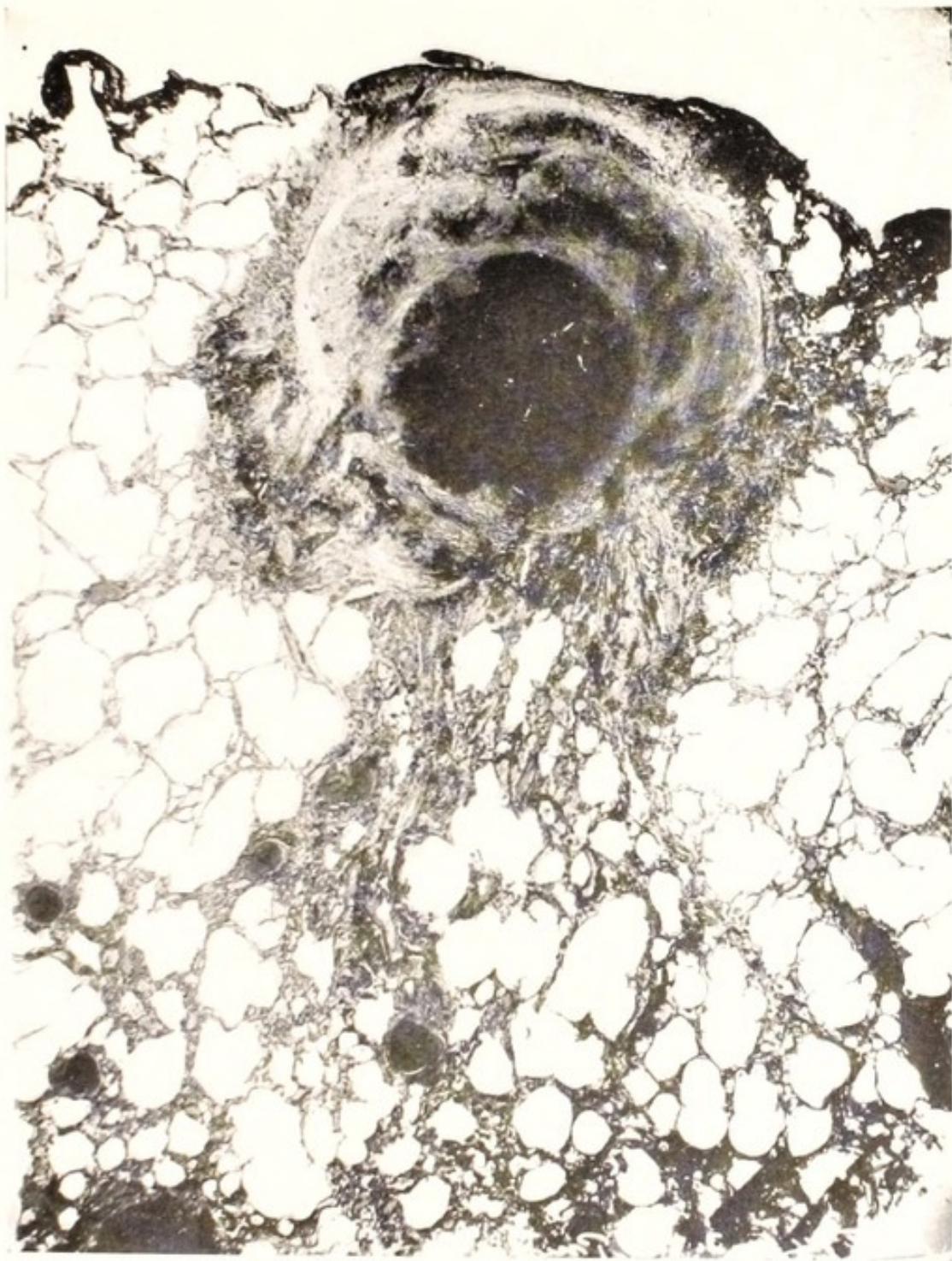


PLATE VII.—A TUBERCLE IN THE LUNG—HEALED

In this photograph of a highly magnified tubercle, which has healed by the formation of scar-like tissue about it, one sees the minute air chambers of the lung surrounding the solid tubercle. At the site of the tubercle the air chambers, and hence the usefulness of this portion of the lung, have been destroyed.

not only to others, but may cause a fresh infection of the patient himself.

Bacteria never rise from thoroughly moist surfaces. One might spread a thick layer of living bacteria of any kind, no matter how infectious, over an exposed surface, and, provided it was kept thoroughly moist, might breathe with impunity the air sweeping in strong currents over it, because the germs always cling most tenaciously to such surfaces. Of course a current of air strong enough to sweep the particles of fluid bodily off from their position would be efficient in spreading the infectious material. The important point which this statement emphasizes is that the breath of tubercular persons is not infectious; the air itself passing over the moist surfaces of the respiratory passages and the mouth carries no germs. The act of kissing, however, might lend itself most efficiently to the transmission of the living bacilli.

So also they may be conveyed through the use of uncleansed eating utensils, dishes, handkerchiefs, towels, etc., used by a consumptive.

There is another way in which tubercle bacilli are transmitted which though less generally recognized is in some respects more significant than the conveyance by dust or contaminated articles, or by direct contact of the sick with the well, and this is by coughing and sneezing. While the tubercle bacillus can remain alive for some time when dried in dust, it becomes less and less virulent, and strong daylight or direct sunlight kills it in a few days or hours. So that the tubercle bacillus in ordinary dust tends to become less and less a menace.

In explosive coughing and in sneezing, fine particles—in sneezing a veritable spray—may be sent forth for several feet into the air. Now in these particles fully virulent tubercle bacilli may be contained, often in great numbers. The fine spray of sneezing frequently floats for a considerable time in the air and may be breathed in by others.

Plate X. shows a Petri plate placed three feet from the face during a vigorous sneeze. The colonies growing after four days on the surface of the gelatin show how many living

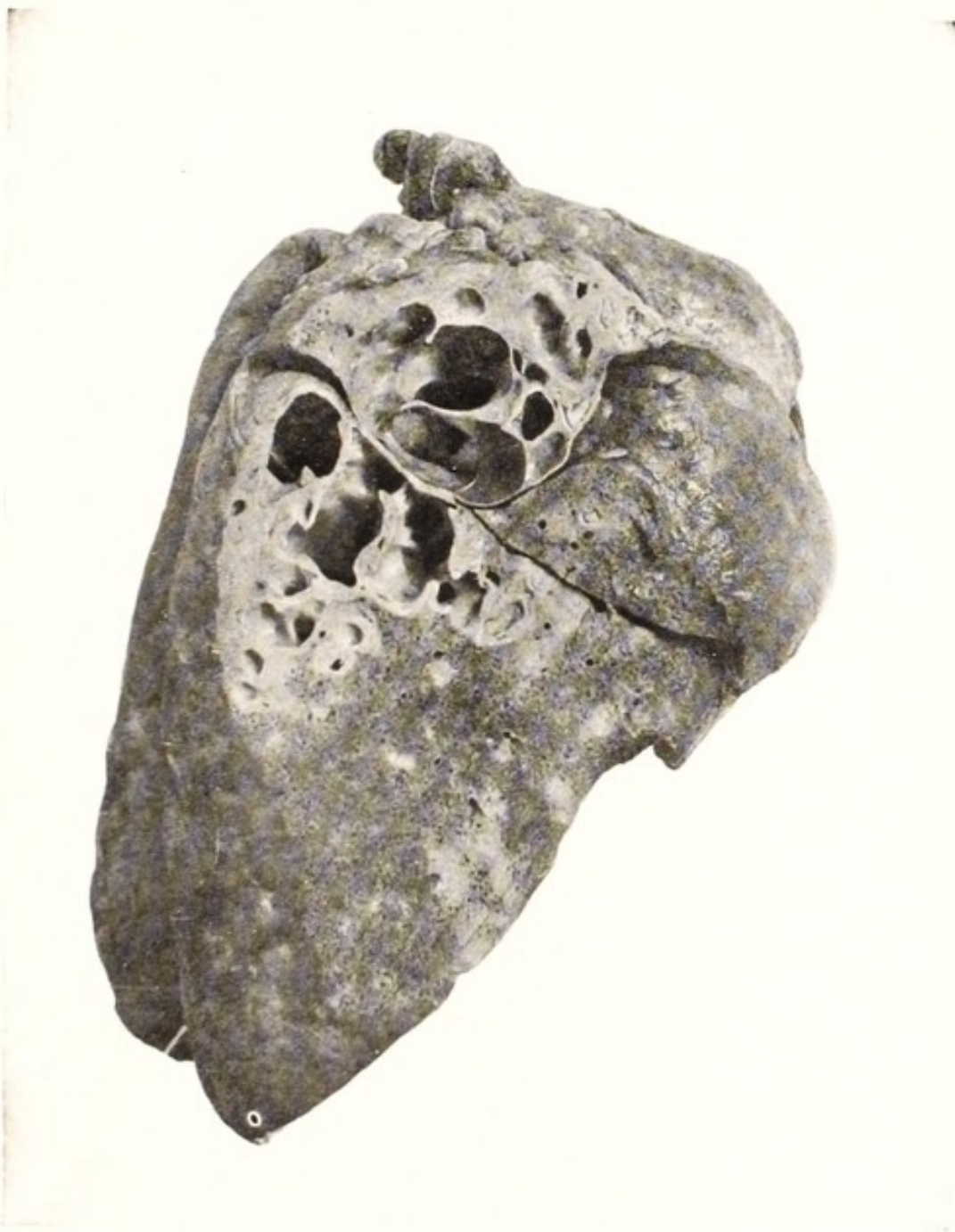


PLATE VIII.—TUBERCULOUS CAVITIES IN THE LUNGS

In the upper parts of this lung, the tuberculous tissues have been destroyed, broken down and cast off, leaving rough irregular cavities communicating with the bronchial tubes. In the walls of these cavities tubercle bacilli thrive and may be discharged in large numbers with the sputum.



germs were widely dispersed in the air. Of course those which fell upon this small dish, three inches across, form but a small proportion of the number expelled.

It is thus clear that both safety and decency require that in coughing and sneezing, the handkerchief, or at need the hand, should be held before the mouth and nose. This obvious rule of propriety is also a counsel of security under all circumstances, since the mouth and nose of many persons, not tuberculous and not even themselves ill, contain infective organisms which, gaining a foothold upon more vulnerable individuals may lead to serious disease.

Now all these facts are extremely disagreeable both to hear about and to tell, and they can only be infinitely distressing to the victims of tuberculosis and to their friends and associates; but all the same they are facts, stubborn, abiding, and significant. The sooner we recognize the truth that every consumptive person may, if proper precautions are not taken, be an actual and active source of infection, not only to those who

immediately come in contact with him, but to those who, either where he is, or where he has been, are forced to breathe dust-laden air, the better will it be for all concerned.

Of course no intelligent person would infer from this statement of facts regarding the sources of infection with tubercle bacilli through the air, that everybody who goes upon the street or enters a hospital or a theatre is going, or is even liable, to acquire tuberculosis. For, in the first place, the infecting material, even under the worst conditions is enormously diluted by the circulating air and the tubercle bacilli are killed by sunlight, so that the individual chances of coming in contact with the dangerous material are slight.

In the second place, the average healthy individual is not predisposed to the disease at all, and could be affected only under especially favorable conditions. Third, the amount of infecting material is apt, in transmission by the air, to be small, and this is a condition which diminishes the chances of danger from such exposure.

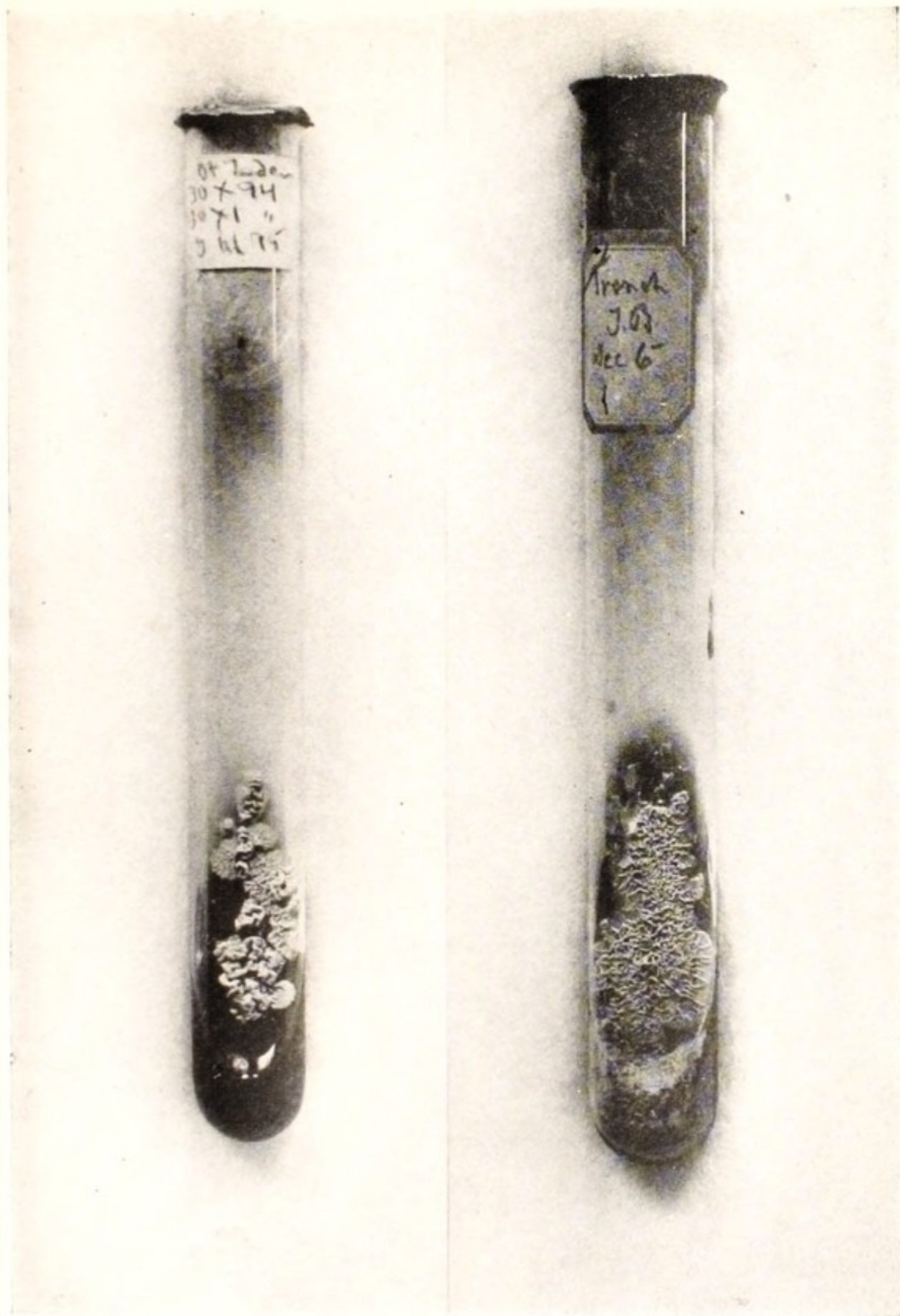


PLATE IX.—CULTURES OF THE TUBERCLE BACILLUS

These cultures are of several weeks' growth on coagulated blood-serum. They were derived from different sources and the variations in growth to be observed mark different strains of the species.

Finally, every individual has in his respiratory tubes an arrangement of tiny cells whose free surfaces are covered with little hair-like processes called cilia. These are ceaselessly waving to and fro, and tend to sweep up and away from the lungs foreign particles which may be breathed in with the air. But notwithstanding all these conditions which serve to guard the exposed individual against the disease-producing bacteria, it still remains true that no man can acquire tuberculosis without getting into his body this particular bacillus from some infected individual or animal.

Now as to tuberculous cattle as sources of infection. Formerly the meat of such cattle, which might be eaten uncooked, was a noteworthy menace. But the State and Federal control of diseases of cattle,—whose health by the way excites a much more vivid interest in governmental circles than does the health of man,—is now so effective that we need not consider it further here. But the milk of tuberculous cows frequently contains virulent tubercle bacilli and frequently comes to the markets.

Infection from this source is more common in young children than in adults, and the bacilli may enter the system through the tonsils or through the bowels. In children the infection may apparently remain latent for years, only revealing itself in small nodules in the neck or chest or abdomen. But there is evidence that in later life these local seats of infantile tuberculosis may become sources of general infection. By boiling or properly pasteurizing the milk for infants, this risk may be avoided.

The conclusions which almost thrust themselves upon us from what we have thus learned about tuberculosis are very plain. Tuberculous meat and milk ought never to get into the markets. Milk contaminated with tubercle bacilli may be rendered harmless by heat.

It would be very difficult to stop by any sort of legal enactment the spread of the tubercle bacilli by means of the air or by personal contact from man to man. But a thorough acquaintance of all persons with the fact that a consumptive patient may be

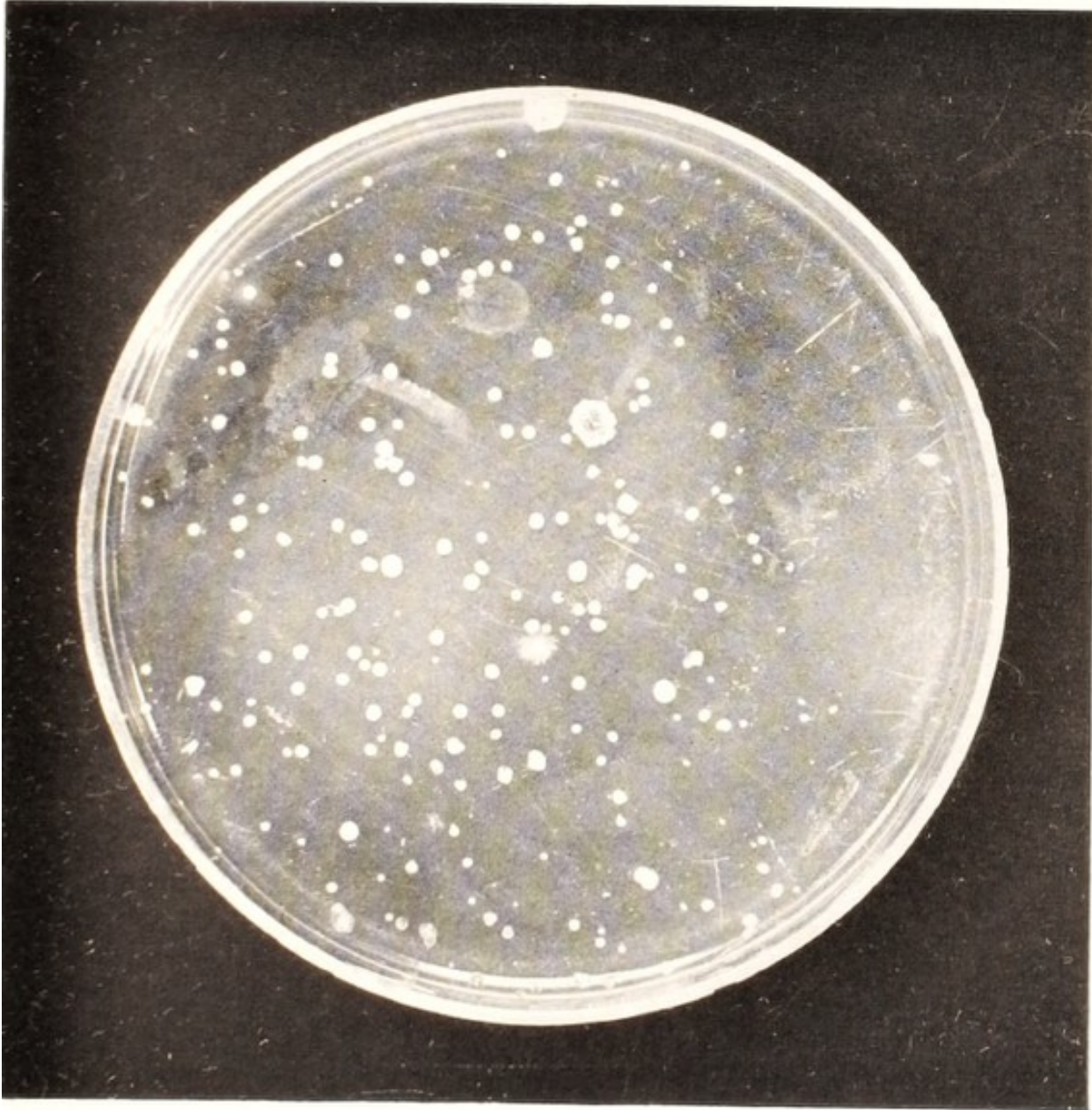


PLATE X.—A SNEEZE PLATE CULTURE

See the explanation in the text.



a source of actual danger to all about him, unless the proper precautions are adopted, would do much to lessen the evil.

Steamship and railroad companies should be obliged to furnish separate accommodations for persons thus affected, so that no well person should ever be forced in the exigencies of travel to expose himself to the liability of infection.

Such regulations and discriminations as are here suggested would of course often be extremely annoying to the victims of the disease and their friends as well as to all immediately concerned. But some such understanding must be come to, unless people are to go on needlessly dying from this most important disease.

The best way of disposing of the sputum of consumptive persons, which, if allowed to dry, may, as we have seen, become the source of active danger to themselves as well as to others, is by burning.

It may be received into small cheap wooden or pasteboard boxes, which are now made and sold very cheap by the druggists, and which

at frequent intervals, together with their contents, should be burned in the stove, furnace, or fireplace. When handkerchiefs or cloths are used to receive the material coughed up, these should be either burned as early as possible, or soaked for several hours in a five per cent. solution of carbolic acid and then boiled and washed. But the use of handkerchiefs and cloths is to be avoided for this purpose as much as possible, because they afford most favorable conditions for the drying and distribution of the infectious material.

The acts of coughing and sneezing should be made innocuous by the use of the handkerchief. Utensils used by consumptives should be separately and properly cleansed and boiled. Kissing by consumptives should be avoided.

But while we are thus led by the knowledge which has been gained of the tubercle bacillus to a more precise notion as to what should be done to prevent the spread of the disease, what has the accumulated lore to offer of hope or comfort to those already stricken? In the

first place, the physician can now say positively by finding the bacilli in the material discharged from the lungs, in many cases even in very early stages, that the lung is out of order.

We now know that consumption is by no means a hopeless disease, especially if it be detected in its early stages. We know that the cells of the body, if they are in a properly active and vigorous condition, have a tendency to destroy the germs. In a large proportion of cases if the disease be early discovered, the wise physician, by recommending life in the open air, improved conditions of hygiene, proper exercise and food, along the lines which Trudeau has spent so many inspiring and fruitful years in developing, may hold out to his patient a good hope of ultimate recovery or of prolonged and comfortable life. Patent medicines and advertised cures for consumptives are one and all futile, fraudulent, and pernicious.

We battle to-day with a known and comprehensible foe, and no longer grope in the dark after a mysterious and unknown enemy.

The hope of the enlightened physician looks out towards a time when we may have learned some direct and efficient means of destroying the invading germs in the body, or neutralizing its poisons. But, in the meantime, by aiding the body's inherent means of cure, he feels himself no longer helpless.

Finally as to individual measures of prevention. Remember that the healthy human body is not good soil for the tubercle bacillus. Keep the body strong and well by good, plain, properly cooked food and plenty of it, and by proper exercise, sleep, and recreation. Look out for the milk. Avoid dissipations whether in work or play or idleness or worry or drink or tobacco. Get all the fresh air you can. Let your breath be deep and strong. Sleep with the windows open. Keep clean. Cultivate cheerfulness. Don't neglect colds, for while they do not directly lead to consumption the vigor of the body may be so lowered by their long continuance as to be more susceptible.

Do what you may as a good citizen to get the people educated to stop promiscuous

spitting, to care for the discharges of tuberculous persons, to let the sunlight and air into living rooms and assembly places, and suppress the dust nuisance indoors and out. Then go about your business and don't fret over tuberculosis.

Of course not all persons can secure all of these desirable things. But most persons can secure some of them. When in doubt consult the doctor.



CHAPTER IX

TYPHOID FEVER AND ITS RELATIVES

TYPHOID fever is one of the serious and common diseases, occurring among all classes of people, which is definitely known to be induced by bacteria. The germs of this disease are little rods or bacilli considerably larger than those which cause tuberculosis (Fig. 11).

There are several forms of low fever, and some other diseases due to various causes, which considerably resemble typhoid fever, and are not infrequently mistaken for it. But genuine typhoid fever is caused by this particular germ, and no other, and is never induced in any other way. The lower animals do not have typhoid fever.

The typhoid bacillus is not known to grow outside the body to any considerable extent

except in milk and when artificially cultivated by the biologist for purposes of study. But it may remain alive for several weeks outside the body in milk, in water, in the soil, or under other conditions.

The typhoid germ in the large majority of cases, enters the body with food or drink by the intestinal canal. When it gets into the intestines, if the conditions are favorable, it multiplies, and enormous numbers of the germs are thus sometimes produced.

Some of these often gain access to the blood and to certain of the internal organs, as the gall bladder and urinary bladder, but many of them either complete their existence in the intestinal canal, or are cast out in the living condition with the diarrhœal discharges which so constantly accompany this disease and in the urine.

As the typhoid bacilli in this disease grow and multiply in the bowels, or elsewhere, they form a soluble poison—toxin—which is



FIG. II.—THE BACILLI OF TYPHOID FEVER

absorbed, just as some kinds of food might be, and carried to various parts of the body, producing effects which we recognize as symptoms of the disease.

The great and important source of infection—the means by which the disease is usually spread—is these discharges from the bowels and the urine containing the living, virulent typhoid bacilli.

Here we have an essentially similar condition of affairs to that in tuberculosis, namely, bacteria of a particular species inducing a disease which, without them, could not or does not, so far as we know, occur and after inducing the disease in an individual, being discharged alive and virulent from the body. Here, as in tuberculosis, although the mode of infection is somewhat different, if all the discharges from persons suffering from the disease could be immediately destroyed, all danger of infection, so far as we know, would be removed. Typhoid fever is thus a communicable and a preventable disease.

Typhoid fever affects man alone, and he alone forms the source of infection. But,

unfortunately, the bacteria are not generally destroyed, and the house-mates of the patient, or those whose water or milk or food supply become contaminated directly or indirectly from his discharges are liable to succumb to the same malady.

But there is another significant source of virulent typhoid bacilli which has only recently become known. It has been discovered that long after complete recovery from typhoid fever the urine and the intestinal waste,—the latter even for many years,—may contain the bacilli, which apparently get domesticated in the gall bladder or elsewhere, and while no longer harmful to their host, are yet fully virulent for others should the chances of communal life bring them into contact with food.

Thus to a single cook has been traced the infection of twenty-six persons in seven different families to whose gastronomic exigencies she uncleanly ministered. A threatening epidemic of typhoid has been started by a person concerned with the milk supply of a large city district, though he had not

for many years been the victim of typhoid. In these two cases cited, the bacteriologist was able to cultivate in the laboratory from the discharge of these two entirely healthy persons virulent typhoid bacilli and show that these were present in enormous numbers.

Such persons, now known to be common among convalescents from this fever, are called "typhoid carriers." The possibility of danger when such persons are concerned with food supplies or food preparation are obvious.

The lesson of this unpleasant revelation is that our standards of personal cleanliness must be more exacting, if we are to be reasonably secure against chance infection from "typhoid carriers."

Altogether the probabilities are that in the majority of cases the typhoid-fever germs are most frequently carried and consumed in milk and in water which have in some way been polluted by human waste containing the typhoid germ.

It seems quite incredible, when put down in black and white on paper, that responsible and sane persons of ordinary intelligence,

knowing that typhoid fever is caused by a living germ, knowing that this is thrown off from the body in the living condition and without being destroyed, is allowed to run through the sewer pipes into the nearest stream or lake, should for an instant consent to have the water of this stream or lake taken from within a short distance of the sewer opening, and often in line of direct current, and distributed in their houses unpurified, and used upon their tables. And yet it would be but the telling of old stories for the writer to cite case after case in which this offence against common decency, to say nothing of good taste, is practised under conditions much more flagrant than these. And then Providence or Fate is shouldered with the responsibility when the careless or ignorant persons themselves, or the innocent victims of their criminal neglect, are stricken with typhoid fever.

Typhoid discharges thrown upon the banks of drinking water reservoirs, or streams, in winter, from the camps of repair gangs, have in many instances been washed into the water

by the spring floods at the cost of many hundreds of lives.

Milk supplies should be especially guarded, because milk, when not kept very cold, is a good culture medium for the typhoid bacillus, so that a slight primary contamination may become fairly pestilential before the milk reaches the consumer.

Oysters, which unscrupulous dealers place in sewage-polluted water to grow plump so that the guise of freshness may impose upon their victims, have many times been the cause of typhoid fever.

Direct conveyance of the bacilli from the patient to nurses, attendants, or friends should not be possible with reasonable care.

Typhoid bacilli may remain alive in ice for many weeks though they gradually die out. It is therefore not without risk, as it certainly is without decency, that one permits the use for drinking of ice which has been cut from sewage-polluted waters.

Flies, which have access to typhoid discharges, may carry and deposit upon human food to which they next address their in-

dustries, virulent typhoid bacilli in large numbers. In the Spanish American war there were many victims of gross neglect in sanitation in whose destruction red tape and the common house-fly played a conspicuous rôle. We shall consider this nefarious insect more at length in a later chapter.

Typhoid discharges should always be rendered harmless at once by heat or be disinfected with carbolic acid or some other effective agent, no matter where they are to be finally disposed of, and this should be done whether the doctor does his duty in the matter, or, as is sometimes the case, neglects it.

So long as the excreta of typhoid patients are not systematically disinfected but are allowed to pass into sewers and cesspools, or are thrown on to the soil whence they pollute watercourses; so long as a high standard of personal cleanliness is not required in those who deal with milk and other food supplies,—we must expect that this typhoid fever, which is a disgrace to our boasted civilization, because wholly unnecessary, will flourish here and there.

Dysentery

There is another bacillus at least first cousin to the typhoid germ to which is attributable certain forms of bowel trouble all the world over, and called the *Bacillus dysenteriae*. There are several types of these small pests. They are transmitted, as are their typhoid relatives, from the discharges of patients mostly through water, milk, and direct contact, or by flies. Like typhoid fever, the infectious forms of dysentery are filth diseases and need not occur with proper attention to sanitation.



CHAPTER X

ASIATIC CHOLERA—TYPHUS FEVER

Asiatic Cholera

HISTORY records many tragic stories of sudden outbreaks of fatal disease which, spreading like wildfire among the people, have brought untold miseries and countless deaths.

In early times these frightful whirlwinds of disease were looked upon as penal visitations of the Supreme Powers, and, in the utter panic which they so often induced, little was done in the way of studying their nature or staying their progress.

Among the more important of these tragic epidemics from which science has withdrawn the veil of superstition, stands Asiatic cholera.

In some parts of the world this disease is constantly present and claims each year a

varying number of victims. But Europe and America are in general free from it, save that now and then, coming from its home in the Far East, it sweeps along the seaboard or over the country, bringing in a greater or less degree the old-time panic and misery and death in its train. Occasionally it finds lodgment upon our own shores and has penetrated into the interior.

Now up to within a few years we have not known what the cause of this disease really was. It seemed to be something which could be brought in ships and wrapped up in clothing, and was evidently communicable from man to man. Such measures of stopping the spread of the disease by isolating the sick, and such general regulation of the diet and habits as seemed from experience best adapted to protect the well, were formulated and practised. But the lack of knowledge as to the exact nature of the infective agent frequently rendered futile the one and uncertain the others.

To-day we know that Asiatic cholera is caused by a little curved bacillus, which on

getting into the intestinal canal of human beings multiplies with such rapidity that within a few days or hours the body may be overwhelmed with the poisonous material which it eliminates as it grows. We know that in certain stages of the disease the living germs are discharged from the body in vast numbers, and that if moisture be present they may remain alive outside of the body for long periods and may even multiply. They can thus remain alive for some time in water and on the moist surfaces of vegetables and fruits and clothing.

There is no good reason for believing that any other germ or organism than this particular curved bacillus ever induces Asiatic cholera, or that the disease is ever caused by anything else. The only known way in which the infective agent is conveyed from man to man is by the taking into the intestinal canal, either by water or food or in some other way, some of the cholera bacilli which have come directly or indirectly from some human victim of the disease.

The germs may remain alive for a long time

if kept moist, and so the disease may be conveyed for long distances in bundles of infected clothing. A few hours of thorough drying, or steaming, or the application of suitable disinfectants, such as strong carbolic acid or corrosive sublimate, readily secures total destruction of the life of the germs.

In Asiatic cholera, as in all of the other bacterial diseases which we have thus far studied, predisposition of the individual is an important factor in the acquirement of the disease. This simply means that there are certain conditions of the body cells which render them less able to resist the incursions of foreign organisms like the bacteria, or which furnish conditions favorable to their growth and proliferation.

We have seen that in tuberculosis this predisposition to the disease, whatever its exact nature is, may be in a certain degree hereditary. In Asiatic cholera, a disordered condition of the digestion appears to favor the occurrence of an attack of the disease. In typhoid fever, analogous predisposing factors seem to determine that when exposed to

the same risk of infection one individual may be attacked with the disease and another not. But alike in all these forms of bacterial disease the particular species of bacteria belonging to each must be present, predisposition or no predisposition, or the disease cannot occur.

Typhoid fever and cholera are often called filth diseases, and to bad food, foul air, sewer gas, and overcrowding, their occurrence has often been attributed. This is in a sense true, since these adverse conditions are apt to induce a state of the body which renders it less resistant than it should naturally be to various deleterious agencies. But no imaginable degree of unsanitary conditions could ever induce tuberculosis, or typhoid fever, or Asiatic cholera without the presence of the particular germ which causes each. None of these diseases can spring up among any class or condition of people without the introduction of the germ from outside.

The recently acquired knowledge of the cause of Asiatic cholera has thus far aided but little in the treatment of persons already

its victims, but outbreaks and the spread of the disease can now be prevented.

Typhus Fever

Typhus fever is an old-time disease, formerly much more common than at present, and most apt to gain a foothold and to ravage among dirty, overcrowded, unsanitary, and ill-nourished folks.

So it used to be called "jail fever," "ship fever," "hospital fever." Some of its forms are mild, others are deadly. At present it lingers, a serious scourge, among certain classes in the near and far East, and in Mexico. In war times it is apt to light up wherever armies or prisoners or civilians are not well cared for and the germ drifts in upon them.

It is through the industrious attentions of the body-lice, *alias*, *Pediculus vestimenti*, that the infective agent is conveyed from one to another. "Kill the vermin; clean up and keep clean," are the watchwords of those who in recent days in the war zones have so successfully battled with this pestilent germ disease.



CHAPTER XI

PNEUMONIA, INFLUENZA, AND COLDS

Pneumonia

PNEUMONIA is an inflammation of the lungs, and is usually incited by bacteria. The species which is the most common incitant of the disease in grown people is called *Pneumococcus*. But in children and sometimes in adults the pyogenic bacteria, which we have looked at in a former chapter, and other forms are also frequently at work.

You see that here in pneumonia we have a disease which, unlike tuberculosis and typhoid, may be induced by any one of various forms of germs and not infrequently several forms act together.

In the most common type of pneumonia in adults the bacteria almost always get

into the blood, so that there is what we have learned to call a bacteriæmia as well as an inflammation of the lungs. In the lungs a great many leucocytes as well as other material accumulates in the air spaces and this sometimes makes the patient short of breath.



FIG. 12.—THE PNEUMOCOCCUS

This shows the delicate transparent capsule which surrounds the bacteria.

The pneumococcus is a very minute lance-shaped organism, which is often surrounded by a transparent capsule (Fig. 12). It can be artificially cultivated, but it is a very sensitive and short-lived thing, easily killed by drying, by sunlight, and

ordinary disinfectants such as carbolic acid.

It is present in the mouth and nose of a considerable proportion of healthy persons to whom it ordinarily does no harm. Just what the conditions are which set this germ at work in the lungs, we do not know very definitely. Old people and infants are particularly susceptible. Feeble, overworked, ill-nourished, debilitated folks, and those who stay in very dusty places are also liable to

pneumonia. It is most frequent in the late winter and the spring because then the general resistance of the body has been commonly lowered by the long overstrain and confinement of the season's work.

Pneumonia is essentially an indoor disease, or if it occur among out-door folks this is almost always because they have been to town or have consorted with house dwellers who habitually harbor the pneumococcus. Exposure to cold and wet, contrary to the common belief, plays but an insignificant part in predisposing to this disease.

In the United States, pneumonia is one of the most frequent and serious of the infectious maladies. Over ten per cent. of all who die are victims of this largely preventable disease.

Through unguarded sneezing and coughing, by the uncared for sputum of those who are suffering from pneumonia, the pneumococcus may be distributed in virulent form to those who do not harbor it.

If we safeguard ourselves against these outside sources of contamination and attend properly to the toilet of the mouth and keep

as well as may be in good physical condition, not neglecting colds or inflammations of the ear or eye, which are themselves often due to the pneumococcus, and keep out of dusty places, we shall have done our part in turning the cold shoulder to this uncanny neighbor to which we are so often unwittingly the host.

In serious pneumonia there is evidence of a profound internal poisoning of the body, doubtless largely due to the great number of pneumococci which are present in the affected lung. These poisons or toxins as we call them, the body cells strive to dispose of as best they may, in ways which we shall consider in a later chapter. For this purpose the body cells must have plenty of oxygen. That means all the fresh air the patient can use. The modern physician, following the way along which Dr. Northrup has so skilfully and persistently led, recognizes this supreme need of fresh air in the treatment of pneumonia, and so with the body of the patient properly protected, keeps the windows wide open. This arming of the body with fresh air is

one of the most effective of the modern ways of fighting bacteria and their poisons.

Influenza

It is popular nowadays for both doctors and laymen to call severe colds influenza or "the grip." But genuine contagious influenza, which occasionally sweeps around the world, a veritable plague out of the Far East, and in one after another of the countries which it crosses puts a large share of the people to bed with all sorts of miseries, is apparently incited by a special bacillus which is very small even for bacilli. It can be cultivated in tubes and is very well known nowadays in the laboratory as well as at the discouraged bedside.

The *Bacillus influenzae* is, however, still somewhat of an enigma, because it, or several organisms quite like it, are found in a good many abnormal conditions, especially involving the respiratory organs. However, we know definitely enough that the influenza bacillus is transmitted from the sick to the

well by the discharges from mouth and nose, especially by unguarded spitting, coughing, and sneezing. It is readily killed by drying and by disinfectants, and does not apparently thrive outside the bodies of human beings. But it may linger alive and virulent for a long time in the mouth and nose of convalescents or those associated with patients, and so it is carried all over the world when once the virulent strain gets started as it did in 1889-91.

The safeguards against influenza lie, as in so many of the infections, in care for the general health, proper care of the secretions, and judicious toilet of the mouth. The doctor knows best what to do when you have got it, and it is well to call him in, for there is much misery while it is going on and serious results sometimes if you are indiscreet, and he can almost always help the body to overcome or outwit the unwelcome intruders.

Colds

Of all the infectious diseases, the so-called "colds" are the most frequent. We have all

had them and all know how unpleasant they are, and how apt we are sooner or later to recover from them. What we do not so commonly realize is that if they are neglected they greatly predispose the body to much more serious infective maladies.

Common colds are incited by a variety of micro-organisms among the more common of which are the pneumococcus and streptococcus, and bacilli which closely resemble, if they are not identical with, a mild type of the influenza germ. Probably several other species are also guilty, but conviction waits upon further evidence. Some forms of colds are distinctly communicable, and run through families or groups of closely associated persons.

The popular impression, crystallized in the name, that they are primarily due to exposure to cold weather, to drafts, to fog and wet, is largely false. All these things, as well as indigestion, overexertion, or anything else which lowers the body's vigor and resistance, may be and doubtless are contributory factors,—the spark which lights the powder. But without the germs there

would be no "colds," as certainly as without the powder there would be no explosion.

People who really live out-of-doors do not often have colds. When they come to town, or get into closed rooms with the sneezing, coughing urbanites, who live and move and have their being in an atmosphere invisibly lurid with bacteria fresh from infected sources, then the outdoor folks catch, not the cold, but the germ which does it.

Colds, like pneumonia and tuberculosis, are indoor diseases and savor of closed rooms, foul and dusty air, crowded assembly places. The vigorous jubilant home-comer from his summer outing, who has been blown and rained upon, who has spent shivering nights under the stars, who has "cooled off" in the wind and tramped in the water, who has prolonged his swim till he was blue, with never a trace of ill, gets a cold a week after he comes back to town. He blames the open window by which he sat to relieve himself of the stuffiness of his city home. But he forgets the ill cleaned dusty car with its scores of germ-dispensing occupants in which he trav-

elled home, or the filthy theatre, never intelligently cleaned at all most likely, in which he whiled away an evening just to get in touch with the spirit of the town. These, and not the fresh air at his window, gave him the real inspirers of his cold.

Keep the body vigorous by good food and water, by plenty of work and play, but don't overdo either. Adopt the old Chinese proverb "Do nothing too much." Get the fresh-air habit. Open the windows in the bedroom and in all rooms. Keep down the dust. Get every possible hour out-of-doors. Keep the skin clean and the body as lightly clothed as is comfortable. Woollen underwear does not prevent colds. A proper toilet of the mouth is not to be neglected. Finally, like a good citizen, join the forces now engaged in securing cleaner air in all assembly places, in cars, shops, hotels, stores, theatres, courts, churches, as well as at home. Frown upon the folks who sneeze and cough and spit in fashion worse than brutish. Then if you do get colds now and then, as you will,—for sanitary decency is not to be won in a

day,—you will have a fair chance for a light infection.

If people with acute colds could and would sequester themselves for a few days and rest while the body overcomes the invaders, it would be much better for them and an active source of infection for others would be removed.



CHAPTER XII

DIPHTHERIA AND TETANUS

Diphtheria

DIPHTHERIA is a disease most frequent in children, in which a membrane is apt to form in the air passages, which may make breathing difficult or impossible. There are also symptoms of serious general disorder, as if the body were profoundly poisoned.

The disease is incited always by a peculiar, often club shaped bacterium called the *Bacillus diphtheriæ* (Fig. 13). It is killed by boiling for a minute or by disinfectants, but may live for months in the air. This bacillus is present in enormous numbers in the membrane, and sometimes gains entrance to the body. But the chief damage to the victim of diphtheria is a powerful poison which the

germ manufactures as it grows, and which is absorbed into the blood. This disease is therefore a *toxæmia*.

The bacillus of diphtheria is readily cultivated in beef tea or on the usual solid bacterial foods, where it produces the same poison



FIG. 13. — BACILLUS DIPHThERiÆ

that is formed in the disease process. We shall return to this diphtheria poison or toxin a little later, when we look at the various ways in which the body protects itself against pathogenic bac-

teria, and the ways which modern science has discovered to help it.

While diphtheria is a very serious disease, the use of antitoxin, the nature of which we shall consider farther on, has robbed it of its greatest terrors and very much reduced its frequency. It is rare in animals.

The diphtheria bacilli are often conveyed from the sick to the well by the material discharged from the mouth and nose, either directly, or by eating utensils, towels, etc. Furthermore the bacilli often remain for

many weeks alive in the mouths and throats of persons recovered from diphtheria. They are frequently found in the mouths of well persons exposed to the disease; also of those, called "carriers," not known to have associated with diphtheria patients.

This is one of many reasons why we should try to avoid exchanging mouth secretions with others by avoiding the use of common drinking vessels or towels, and by more seemly sneezing and coughing; why children should not suck pencils and pass them on, or indulge the friendly impulse to share the handkerchief or chewing gum. This is why adults, as well as children, should not insalivate the leaves of books and papers as they turn them over by wetting the fingers in the mouth. Finally the story of the diphtheria bacillus as of the pneumococcus and the tubercle germ suggests the propriety of less catholicity than is usual as to whom, and more circumspection as to how, we kiss.

Tetanus or Lockjaw

Tetanus is induced by a remarkable bacillus

common in the cultivated soil, in street dust, and in the droppings of the horse and other herbivorous animals. The bacilli when growing in the body produce an intense poison, which acts especially through and upon the nervous system. Thus powerful spasms of the



FIG. 14.—TETANUS BACILLI
Showing spores

muscles are produced, and when the muscles of the jaw are affected, they become rigid, hence the common name lockjaw.

The bacillus of tetanus does not grow well in contact with oxygen, and when it finds itself under unfavorable conditions for growth, it forms a spore which is very resistant to external influences, and drying, heat, disinfectants, etc., which ordinarily kill bacteria. Then it stands pat and waits for something better to turn up. The bacteriologist, however, can cultivate it by shutting oxygen out of his tubes and plates and consulting its peculiar tastes in other ways. The bacillus when forming spores is shaped something

like a tennis racquet, with the shiny spore in the larger end (Fig. 14).

The horse and some other animals only occasionally develop tetanus, though one great source of the bacillus is horse manure.

Humans get tetanus by dirty wounds, usually bruised or punctured. Pure cultures or spores of the germ are not apt to induce tetanus in wounds, but when other bacteria or dirt are introduced into a wound with the tetanus bacilli these are apt to grow. Thus it is that although spores of the bacillus of tetanus are very widely distributed in nature, the disease is not common, because it is only in punctured or lacerated wounds, in which spores and dirt are lodged together, that the proper conditions exist for the growth of this finicky citizen. This is why those who care for horses, those who handle manure, and the boy who celebrates the "Fourth" with a toy pistol are the most frequent victims of lockjaw. There are some regions in which the soil contains a great many spores, so that tetanus frequently follows even slight punctured wounds.

Careful cleaning and disinfection of dirty wounds, especially those which are lacerated or punctured, is the proper safeguard against this common bacillus.

It is finally noteworthy that while in most of the bacterial diseases the infectious agent is transmitted more or less directly from the sick to the well, and is usually more virulent the more direct and recent the conveyance is, we have in tetanus almost the only example of pathogenic bacteria widely and persistently contaminating the soil. But it is so particular in its habits that it is only now and then that it falls afoul of human beings.

It has been possible through experiments on animals to prepare an effective antitoxin for the tetanus poison. Its usefulness is, however, considerably limited by the fact that the symptoms of tetanus do not develop until the germ toxin has gained a powerful hold upon the nervous system, when it may be too late to neutralize it with the artificial antibody.



CHAPTER XIII

A ROUND-UP OF UNDESIRABLES

Meningitis

THERE is another ball-shaped microbe or coccus closely related to the pneumococcus which is responsible for a very serious communicable disease prone to affect children by an inflammation of the covering membrane of the brain and spinal cord. As this membrane is called the meninges, the disease is named cerebro-spinal meningitis, and the microbe is called the *meningococcus*. It is found sometimes in the nose and throat of its victims and their associates. It has been cultivated and carefully studied. Dr. Flexner at the Rockefeller Institute for Medical Research in New York has secured from horses treated with cultures of the meningococcus

a curative serum which has been used all over the world and has saved many lives.

Gonorrhæa

There is still another of this uncanny family of cocci called the gonococcus, which is the inspirer of great misery and leads to many deaths.

It is the nemesis of the licentious and debauchers of the racial instinct, and in their retribution their many innocent victims share. It is the cause of a large part of the blindness of infancy.

Syphilis

Syphilis is a disease which is primarily almost always dependent upon an infringement of the laws governing the racial instinct, and is usually the penalty of depraved associations. Retribution to the offender often lasts through life, and the innocent are often hopelessly involved.

The inciting agent of syphilis is a minute spiral bacterium whose life history is not yet

fully known, since it has been artificially cultivated only recently so that it could be studied free from complicating conditions.

The infective organism is naturally limited to the human race, though monkeys can be experimentally infected.

Except for the few instances in which by accident the infective agent has been conveyed, it is seldom known to be a source of danger to those of honorable life, except through intimate association with its victims.

The Plague

The plague, or "black death" as they called it when it ravaged Europe in the middle ages, has a very ancient and sinister history. You may read about it in the pages of Bocaccio or Defoe. It had largely disappeared from Europe for a century and a half. But in the latter part of 1900 it started afresh in China and India, and gradually worked its way into the Americas. It has never fairly gained a foothold in the United States, thanks to effective quarantine, except in San Francisco,

where for a long time there have been scattering cases.

The plague bacillus is short and plump and grows very easily in cultures and in such characteristic ways that it is readily recognized. It is easily killed by drying, sunlight, and disinfectants.

In one form of the disease pneumonia is a prominent feature, and then the germ may be transmitted from the sick to the well by the discharges from mouth and nose.

But in severe epidemics of plague the number of persons affected is so large that some other mode of transmission of the bacillus than by personal contact has to be assumed. And here we come upon a keen reminder that some of the lower animals which we cordially despise, as is the case with the house-fly, are significant factors in the discomfort which man derives from inheriting the earth.

It has been found that in plague epidemics rats share with man in the predilections of the plague bacillus, having an enormous mortality of their own. The evidence indeed is strong that man derives his plague bacilli

from the rat. But the question is how? Rats do not often bite men or closely consort with them, nor do they notably contaminate human food. But rats have fleas and when these bite infected rats they borrow the bacilli with the blood and if then they bite a man the bacilli may be directly introduced into his system.

Much study has shown that, in fact, in countries and regions where plague prevails the rat and the flea are potent factors in transmission.

In California where plague has been lurking for some years, some of the ground squirrels have become infected with plague bacilli and while this is not yet of threatening importance, it is disquieting that the infective agent has not long since been completely destroyed.

Smallpox and its Relatives

It is very interesting that with all our study of micro-organisms and long familiarity with these diseases, smallpox, measles, and scarlet fever should still remain riddles among the common infections. These diseases are all

characterized by an eruption on the skin. The old Greeks knew them and called it a "flowering out," and so we call the lot "the exanthemata." We do not know what incites them. The search for bacteria has thus far failed.

It has been conjectured that minute animals—protozoa—may be to blame. Some morning we shall probably learn in the papers that a tired-eyed worker in the laboratory has found the clue, and we shall wonder that we did n't always know it.

But though we do not yet know what incites them, we have for one—smallpox—so efficient a preventive in vaccination, that it has largely lost its terrors in civilized and intelligent communities, and has ceased to figure largely in health statistics. This happy state has been secured through the wisdom and vigilance of health authorities, which must be ceaselessly maintained.

Hydrophobia or Rabies

Here is another infectious disease usually acquired through animals, in this country,

usually the dog. The nature of the infective agent is unknown. It is apparently not bacterial. Learned folks guess it to be a protozoan.

But nevertheless here, as in smallpox, a most effective method of prevention has been devised by Pasteur, so that one bitten by a mad dog has the best of chances to escape the disease if he will but promptly apply for treatment to the appropriate laboratories maintained by health departments and others. The nature of the preventive treatment in hydrophobia is considered briefly elsewhere in this book.

Malaria

This wearisome malady is not induced by bacteria and so is only smuggled in here to round out the census of common infections. It is due to a tiny animal, a protozoan, which is conveyed from the sick to the well through the bite of a particular species of mosquito called *Anopheles*. The germ itself is named *Plasmodium malaricæ*. It takes the two of

them to get the better of their big brother, man.

But man has more brains and has found out that the weakest link in the chain of his inoculation is the mosquito, and when he drains the marshes in which most of the little buzzing brethren breed, and screens his windows against the plebeian minority to whom stale water in old bottles, tin cans, water butts, and puddles is birthplace, his "shakes" disappear and he becomes a worthwhile citizen again.

Yellow Fever

This is a tropical disease but may flourish in temperate climates in summer. It ceases when the frost comes. It is certainly infectious, it does not affect the lower animals, and we do not know what living thing incites it. It was formerly supposed to be contagious and the infective agent carried in the clothing. But through a series of brilliant recent researches, it is now known that the yellow-fever germ is carried from the sick to the well

by a particular species of mosquito called *Stegomyia*, which sucks blood and the parasite from the patient and transfers it to persons whom he may later visit.

There is a very fascinating story in the discovery of the yellow-fever mosquito and his significance to man, but we cannot tell it here. We may only say that when they screened the mosquito away from the fever patients so that he could not get infected blood, they stamped out yellow fever in Havana, and can control it anywhere by keeping tab on *Stegomyia*.

The germ, though certainly present in some form within the small bailiwick of the infected mosquito, has eluded discovery. It seems to be one of a baffling group of living things inciting disease, so small that they are called "ultra microscopic."

Infantile Paralysis

Recently Flexner and Noguchi, at the Rockefeller Institute in New York, have brought to light the minute germ which is apparently

the inciter of this sinister and pathetic disease of childhood. This was done by the adaptation of a clever combination of choice food and congenial surroundings, suggested long ago by Theobald Smith for cajoling coy bacteria to grow in strange places.

The disease is often fatal, and when recovery follows, its victims are frequently handicapped through life by paralyses and contractions of the muscles. This shows that the germ poisons have damaged certain parts of the nervous system.

The germ is so small as to be almost beyond the limits of human vision even when armed with the most powerful microscopes. It appears to be conveyed from the sick to the well through the secretions of the mouth and nose, in coughing, sneezing, and otherwise. Well persons attendant upon the sick may act as carriers of the germ. Thus here, as in so many other germ diseases, intelligent cleanliness is our best safeguard against infection.

The doctors call infantile paralysis poliomyelitis, which means inflammation in the grey matter of the central nervous system.

Whooping-cough and *Mumps* are infective maladies whose germs are still unknown.



CHAPTER XIV

SAFEGUARDS OF THE BODY AGAINST DISEASE

WHEN we try to learn more about the human body than we can by observing its form and structure and the various obvious things which it can do, we are led back to the time when that mysterious potency called life stole in upon the earth in the primeval silences. And we are obliged to trace the changes which, through stress of circumstance, have slowly shaped, out of a single cell, the various cell communities and their marvellous correlated activities which make the human being of to-day.

All these changes have been brought about by the adaptation of form and activity to new environments. And we can discern here and there through all the various cells and organs,

and all the things they do, the marks of earlier stages of development.

The uncouth ancestral being, which by and by was to be moulded into man, once had need of more bowel space than he now requires. But when this became unnecessary a segment of it wasted away, leaving a weazen remnant which we call the appendix, and which gives some folks a good deal of bother now and then. There was a weak spot in the lower abdomen once when man's progenitor went on all fours. This interested him not at all then. But when his descendant got along in his development so as to stand up on his hind legs, the pressure of the bowels on this weak spot was much increased, and so some people find a knuckle of intestine pressing out in what we call a rupture or hernia. Thus we might go on a good while with these marks of forgotten histories cropping out occasionally in the last of the long ancestral line.

But what especially concerns us now, is the more subtle marks of evolution in the intimate performances of the body cells. Whatever capacities they now possess and

use so cleverly for the welfare of the whole community, they have acquired, as we have said, through long ages of adaptation to new conditions. By adaptation we mean making the best of it. Now this power of adaptation the body cells possess to-day, subject to the work and strain of ordinary life. The body cells can adapt themselves to new kinds of food and to more or less of it, to changes of temperature, to new forms of work, and so on. Life is, in fact, a constant adjustment to varying conditions. If these new conditions become too extreme, the efforts of adaptation are exaggerated, the capacity is overstrained, the rhythm of correlated activities is broken, and this is disease. But the pull of the ancestral experiences, which we call heredity, is ever back to the balanced activities called health. This pull of the ancestral experiences is what the doctors have in mind when they abandon the Saxon tongue and speak of the *vis medicatrix naturæ*,—the healing power of nature.

Now, all this is important in studying the safeguards of the body against disease, be-

cause the biggest safeguard which the body has against disease is this capacity of the cells to adapt themselves, within reasonable limits, to new and often adverse conditions. This is combined with their habit, acquired through several millions of years of inherited experience, of getting back into the old ways again as soon as possible. These are the powers which the doctor must work with and not against, with his regimen and diet, with his fresh air and sunshine, with his counsel and cheer, as well as with his less important offerings of drugs. These body cells tend to get back at their tasks again after the adventures which circumstances force upon them, because their ancestors, all the way up the line, did so and survived, weaving their experiences into the vitals of their descendants; while collateral branches which did n't do it, perished. Some folks call this the principle of the survival of the fittest.

Another of the body's most potent safeguards is its power to dispose of poisonous substances, which are developed within it, or get in from outside. With our food we

take in a very nondescript mess of chemical substances, and incidentally a good many millions a day of bacteria. The intestinal processes spell death to myriads of bacteria with which our uncooked foods are mingled. The chemical substances are pulled to pieces by the digestive juices, and a part of this refined food-stuff gets into the blood. The residue is regularly and safely disposed of. The part which gets into the blood is robbed of some of its harmful ingredients in the liver or elsewhere. The rest of the internal waste gets out through the kidneys or lungs or by the sweat-glands of the skin. The selected elements of the food finally come to the body cells, which proceed to tear it further to pieces, use what they want, and again set free another set of residues, some of them very poisonous if retained in the body, but in health got safely rid of again by the kidneys, lungs, and skin.

Thus it is that while in the ordinary course of life we are constantly beset with varied and subtle poisons, the mechanism of the body is so nicely adjusted that we are saved from harm by our cells, some of which feed

and thrive upon poisons which without these curious proclivities would inevitably damage or destroy them, and us. This power of the body cells and organs to destroy and dispose of internal waste and poisonous material is, then, the second of our great protective agencies against disease.

The bacterial poisons are disposed of through the very agencies which are constantly guarding our bodies from harm by the home-made poisons which we ourselves elaborate. These agencies consist largely of new chemical unions into which the poisons are forced to enter, thus losing their identity and their harmfulness.

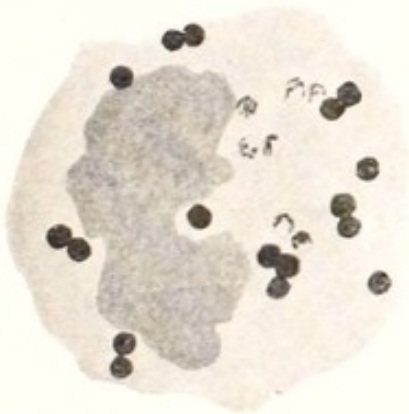
Another important safeguard of the body is certain tiny cells, the most significant of which we have glanced at in an earlier chapter, the *leucocytes* or white-cells of the blood (see Plate XI., 1). Although the body can maintain its form and structure and go on doing its work, often beyond the orthodox threescore years and ten, it is in fact constantly changing. New cells are forming and old ones are dying, some are damaged and must be speedily



1



2



3



4

PLATE XI.—LEUCOCYTES AND PHAGOCYTES

1.—Shows a leucocyte or white blood cell with its irregular shaped nucleus and the translucent delicate cell-body.

2.—Shows a leucocyte which has taken into its body particles of soot, breathed in by its owner from dusty air. This leucocyte is thus, for the time being, a *phagocyte*.

3.—This phagocyte has taken into its body several bacteria—micrococci—a few of which have been partially destroyed.

4.—This is one of the larger phagocytes of the body which has in its interior, portions of other smaller dead cells. These are here undergoing disintegration.



replaced, and there is everywhere more or less wear and tear. Now in all these changes there is first and last a good deal of dead stuff to be disposed of.

While other cells here and there lend a hand in this scavenger work it is the leucocytes which bear the brunt of it, and it is in truth a busy life they lead. Fragments of dead cells or tissue (Plate XI., 4), particles of foreign material which accidentally may have got into the tissues, they engulf (Plate XI., 2). Some of these they sooner or later digest and thus dispose of, or if this be not feasible, they carry them off to safe places of deposit within the body. The regular leucocyte dumping grounds of our busy interiors are the so-called lymph-glands or lymph-nodes, of which we have many snugly stored in appropriate places—in the neck, the armpit, the groin, at the root of the lungs, and within the abdomen.

Here various types of scavenger cells foregather and work over their never ending supply of booty from the farthest recesses of the body. If through the subtle chemistry of their own juices they can convert the stuff

into soluble or nutrient or harmless form they do so. If it is too intractible for that, it is stowed away on the spot in dormant cells or in the crannies of the node, where it is less harmful than in the thoroughfares or special workshops of the great community.

These leucocytes are *par excellence* the wandering cells of the body—for not only do they share with the red blood cells in the passive transportation, which the blood and lymph currents afford, but unlike the red cells they have noteworthy locomotive capacities of their own; so that they can crawl about in the minute crannies of the tissues where the tiniest fragment of a useless particle is to be found. A few other cells share in the locomotive powers of the leucocytes.

The leucocytes and other cells which take foreign particles into their interiors have received a special name—*Phagocytes*—which means “devouring cells.” This is only a sort of trade name, suggesting one of many occupations of the white blood cells, and when other cells share this special task they, too, become for the moment phagocytes. Thus

the leucocytes do not cease to be leucocytes when they become phagocytes, any more than a son of Erin ceases to be an Irishman when he becomes a plumber.

The leucocytes, as well as some other body cells, have the further useful capacity of secreting and under certain conditions setting free, such chemical substances in solution as dissolve refractory tissues, dead bone, for example, and so clear the ground for new growth.

Thus far we have been considering harmful stuff in the body, such as poisons and dead particles, and the ways in which the body protects itself against them. Now let us look at some more striking aliens, themselves alive, which often intrude upon the balanced life of the healthy man.

The presence of bacteria in the body is of varying significance, depending upon where they are and what their pedigree. The healthy skin keeps out most of them. The ever swinging cilia in the windpipe sweeps them out in hosts. In the mouth and nose many are destroyed, but many lead here a placid,

harmless life. Along the digestive canal they swarm. But these are mostly harmless, some even lending a hand, perhaps, in reducing our complex foods to simple forms. The tonsils are rather weak points in the body armor, for through them several objectionable germs, among them the tubercle bacillus, sometimes enter.

When bacteria get into the real interior—for the lungs and bowels we may wisely remember, are only infoldings from the exterior—when they get into the very tissue itself, and into the blood, even then nothing very startling happens, as a rule. The power of the leucocytes and other cells to take up dead stuff comes in handy here, for when the average bacterium is encountered in the homes of the leucocytes, it is either engulfed forthwith or poisoned first and swallowed afterwards (Plate XI., 3).

It is only now and then with the very few of the thousands of species of bacteria which are co-inhabitants of the earth with us, that difficulties arise.

There are doubtless a good many interesting

stories in the relationship of bacteria to man if we could only wander back along the ways of evolution. For we have all grown up together through the ages, we and the bacteria, each adapting himself to the requirements of the other. When this mutual adjustment is secured, we do each other no harm. Our cells and the bacterial cells then work hand in hand. Infectious diseases are the efforts of adaptation to conditions which have not yet become usual. That the invading microorganisms in infection also have their hour of storm and stress, as they encounter the damaging forces which our cells command, is proven every time we get well.

Bacteria, as we have seen, make trouble in the body very little by their mere physical presence, but by poisons which some of them form and set free as they live and grow, or which they store up to be liberated when they die and break to pieces. So when in our cherished interiors the poison-breeding bacterial cell encounters our well bred body cell, it is a battle in which the weapons are poisons. For some of the fluids and digestive juices

which our own cells elaborate are just as much poisons for the bacteria as is their venomous stuff for us.

In the end it is the old story of the survival of the fittest. When these two types of cell meet, each trying to get a living in its own way wherever it has been stranded by the wave of circumstance, a new environment is established for the body cell and for the bacterium. And what we dramatize as a battle, is really only the attempt of each to adapt itself to the new conditions furnished by the other; so that each can go on and get a living. The one which adapts itself most readily and completely and quickly wins, by survival.

We please our fancy sometimes, by making heroes of the leucocytes, dashing at the intruders in their hereditary bailiwicks, regardless of the risks which they so hardily incur. Let us not indulge in too much of this, lest haply we too be found among the nature fakirs. For, in fact, they are impotent pieces of the game played by physical and chemical forces, and they have to set about the battle willy-

nilly, just as much as the magnetized needle has to swing to the north, quite without concern whether the ship does or does not go upon the rocks.

The thing which we want to glean from the rehearsal of this cell contest is, that in both animal cell and bacterial cell the capacities of ordinary life, in this emergency, are set vigorously at work to meet the requirements of a new situation, and upon the way they meet it depends their fate. But while the two kinds of cell may sway and modify a little their every-day functions in their own protection, they no more forge new weapons, than would a stone-mason who should rap an imminent foot-pad over the head with his hammer.

When these doughty cells succumb to the bacterial poisons which they encounter, they are picked up as dead stuff by other forms of cells (Plate XI., 4), and with the dead invading hosts are decently disposed of.

So at last we see that the body protects itself against bacteria and their poisons by the use of the same agencies which it has made

effective through ages of experience in keeping its interior fresh and wholesome and clear of its own refuse and the intruding flotsam and jetsam of a dusty world.

But through all these marvellous adaptive processes by which the body maintains its balance among the pitfalls of a sorely jostled life, is felt the steady pull of heredity back to the line of health. This we fondly dramatize as the beneficent touch of good old Mother Nature. But it really is the ultimate impress upon the cell republic and its citizens, every one, of the unrecorded adaptations to the conditions of each hour, whether for good or ill, since the first living cell appeared, surprised and lonesome, upon a hitherto inanimate earth.



CHAPTER XV

HOW SCIENCE HELPS THE BODY IN INFECTION

WE have seen how, through many excellent arrangements in our cells, we manage to keep alive in spite of a great many threatening conditions. In fact, good Mother Nature—let us again risk the phrase—makes a pretty good job of it, in a large proportion of cases, whether we know how she does it or not. But there are a great many people on the earth and a great many, for them, malignant bacteria. The body machines of many folks are woefully abused or sadly handicapped in the race of life. So in the long run Nature scores many failures. If you want to get an idea how many there are of these, look at the death-rate from bacterial diseases in any district of the United States in a single year, and you will see that

she seems to be overworked or lacks resources. In New York City, for example, in 1907 there were between 8,000 and 9,000 deaths from tuberculosis of the lungs; nearly 700 from typhoid fever, about as many from scarlatina; over 1,600 from diphtheria, and more than 600 from cerebro-spinal meningitis. This looks as if Nature needed help, as in truth she does.

Now let us see how science is trying to lend a hand.

It is clear, in a general way, how the body protects itself against harmful bacteria by its power of neutralizing their poisons, by destroying them with its cells, and by its inherent tendency to get well, whatever happens. But science must know more than this. If it is going to help to neutralize poisons it must know more of the processes which the body uses for this purpose. If it is to reinforce the efforts of the cells in killing and destroying bacteria, it should get behind the scenes and learn, if possible, how this is done in the single-handed conflicts which mark each hour of life.

Animal species differ in their capacity to protect themselves against germs and their poisons. Many bacteria deadly to some of the lower animals are harmless to man, and *vice versa*. This freedom from danger of special microbial invasion is called *immunity*. Since it is born with the individual, it is called *natural* or *hereditary immunity*. Some of the factors concerned in this we have already considered.

But there is another phase of immunity which we must look at a little more closely. People who recover from some of the infectious diseases, such as small-pox, measles, scarlet fever, and in a less degree from typhoid fever, diphtheria, and others, are protected for a longer or shorter time from a subsequent attack. Such people enjoy, while it lasts, what is very properly called *acquired immunity*, an immunity acquired through an experience of the disease itself. Now what is it in the bodies of these people who have successfully weathered an infectious disease which protects them from another attack? If we could answer this question we should evidently be

well on the way toward understanding the nature of acquired immunity. They must be in some way different from their fellows and must have either acquired some new qualities which they did not possess before their disease adventure, or old protective agencies must have been reinforced.

How light has been thrown, little by little, on this important subject by the busy self-sacrificing workers, both in the laboratory and at the bedside, makes an interesting story which we cannot now stop to tell. But the fact is, that when certain poisons, especially those formed by bacteria, get into the body, some of the body cells proceed forthwith to make and set free chemical substances which unite with the poisons, changing their character and making them harmless. Through this action of his cells, the recovering victim of an infection destroys the poisons as they are made. The bacteria which make the poisons are thus robbed of their chief significance and do not particularly concern the patient any further. So he gets well. But something more may happen. His cells,

which were stimulated in the poison-emergency to produce neutralizing stuff, speedily fall into the habit of making it, and go on doing so, often for a long time, after the master of the cells has recovered and after his actual necessity for it has ceased.

Now at last we see why he cannot soon suffer from the same disease again. His body contains a good deal of the protective, poison-neutralizing agent, and his cells go on making more for a time, so that he goes about poison-proof. By and by, however, the old hereditary pull back to the usual routine is felt, the emergency cell activity wanes, the excess of protective material disappears, and the acquired immunity passes away. So the hero of this dramatic story of disease takes his place again among ordinary mortals.

Now in scientific speech certain poisons are known as toxins. And so this cell-made emergency stuff, which robs the toxins of their power, is known as *antitoxin*. Antitoxins are effective only against the special poisons which inspire the cells to their production—that is, they are specific. An anti-

toxin for the diphtheria bacillus poison, for example, would not at all protect against the tetanus poison, or *vice versa*.

As soon as research had gone thus far into the problem of immunity, the thought of the lonesome worker in the laboratory turned, as it is wont to do, with every new outlook, toward the needs of suffering mortals. If in the body of an infected animal, as is the case in man, this protective antitoxin may be formed in excess—so ran the thought of the investigator—might it not be possible to treat animals with special forms of bacteria or their poisons, and when their cells have been educated to the overproduction of the specific antitoxin, draw off some of the blood containing it, and by introducing this into the body of a human victim of the disease, save him from impending death by poison? This significant and humane suggestion has been worked out into a practical system. And now the world over are laboratories from which are derived life-saving antitoxins of various kinds.

Among these the first to be secured and the

most important is the antitoxin of diphtheria. This is prepared from the horse. It is not necessary to cause the horse to endure diphtheria, as we know it, at all. For if the poison which the diphtheria bacillus sets free, when it is grown in beef-tea cultures in the laboratory, with all the germs filtered off, be put into the horse, his cells get to work, just as ours do when we have the disease, diphtheria, and just as his would if the bacilli were allowed to grow in his body. Presently antitoxin begins to mingle with his blood.

The horse lends himself readily at first to small, then to increasing doses of the potent diphtheria poison. He becomes readily immune and he is so big that he furnishes a large amount of blood without apparent inconvenience. When the animal is poison proof, no longer showing any ill effects to doses of the toxin so large that if given at first they would have been inevitably fatal, he is bled from a large vein in the neck. The blood is set in a cool place and clots, clear fluid, the serum, separating from the rest. This yellowish clear serum contains the antitoxin.

All these operations are most carefully done so that the antitoxic serum is pure and clean, and it is introduced beneath the skin of the patient with a small syringe made for the purpose.

This is a hasty outline of the story of diphtheria-antitoxin-making. You see, the cells of the horse make antitoxin to protect themselves and him from the toxin which is artificially introduced by his skilled attendant. This antitoxin will neutralize diphtheria toxin wherever it encounters it, whether in a test-tube or in the body of a poisoned child facing imminent death. The child is struggling to make what antitoxin he can for himself. If his cells can make it in plenty and make it soon enough, he may recover unaided. But the antitoxic serum of the horse is just as good; it works quickly, it raises high the chances of a successful issue.

Since the introduction of diphtheria antitoxin the mortality from diphtheria has been reduced quite 75 per cent. Just what this means in the saving of life and in the relief of suffering, only those can realize who

saw diphtheria in the old days and have read the sinister story of the early statistics.

But the antitoxin of diphtheria is also of the greatest value in the prevention of the disease among those who have been exposed to infection in families, schools, and elsewhere.

The immunity which the child secures through the diphtheria which it survives, is won at great cost and risk. It is called *active immunity*. Through it the body cells have adapted themselves to a new unfavorable environment. On the other hand, the immunity conferred upon the child by the antitoxin which the horse manufactures, is called *passive immunity*. The effect is immediate and quite under control. But the protection is short-lived and the body soon eliminates the foreign agent from its blood and tissues. The antitoxin does not destroy the diphtheria bacilli. The body cells take care of them as soon as the blight of the poison is effaced.

In similar fashion valuable curative antitoxins are made for cerebro-spinal meningitis and for tetanus, and, though less successful, for a few other infections.

Of course the eager workers in the laboratories have tried to get antitoxins for many other of the bacterial diseases. But somehow the method did not seem to work so well in all. There are many obvious reasons why this should be, but they are too complex to consider here. There is little doubt that as research goes on still further discoveries will be made of effective antitoxins.

In the meantime, however, the student of bacterial diseases has turned to other phases of the protective mechanism. Active immunity can be secured in other ways than by the weathering of an infection. Thus it has been found that if a mass of disease-inducing bacteria, from an artificial culture, be killed by heat and portions of these be introduced into the body, its cells gradually adapt themselves to the poisons which the dead bacteria contain, so that the body is in a measure protected from an attack of the disease of which they are the regular incitants.

Thus with typhoid fever, Asiatic cholera, and plague, important practical results have been secured. The persons thus forearmed

are found to be much less liable to acquire the disease in prevailing epidemics. These results are due to the fact that some pathogenic bacteria, instead of setting toxic substances free as they grow, store them up in their bodies. Later when these are killed by heat and degenerate, the toxins are set free, inciting the body cells to their protective activities.

We have thus far been considering the ways in which the body may be helped to free itself from the presence and action of poisons produced by disease-inciting germs. Now what can be done to help the body to kill and destroy the bacteria themselves and so stop the poison fountains at their sources?

It has long been known that the body fluids kill bacteria in enormous numbers, even those of serious infectious maladies, and we have much knowledge of the chemical agencies by which this is accomplished.

It has been shown that there are two groups of substances in the body fluids, one at least of which may be increased in artificial immunization, which, when acting together,

have the power to induce disintegration and destruction of bacteria. This action is called *lytic*, which means dissolving. Thus we now speak of the destructive action of the body fluids on the bacteria as *bacteriolytic*. There is reason to believe that one of the most important agencies of the body in protecting itself against invasive micro-organisms is this bacteriolytic power of its fluids. This power is the same as the body has always made use of in disposing of its own dead or useless cells, but it is here diverted to new ends to meet an emergency.

While there appears to be in this new knowledge of bacteriolysis the brightest promise of future practical usefulness in the control of infection, we need to know more about the cells which make these protective substances and the conditions of their formation before we can effectively lend a hand.

But it has been found that by introducing into the body, in certain infections, some of the killed bacteria which incite them, the body cells are stimulated to produce substances which so alter such of these bacteria as are

already at their destructive work, that they become an easier prey for the ever vigilant phagocytes (Fig. 15). The bodies of the killed

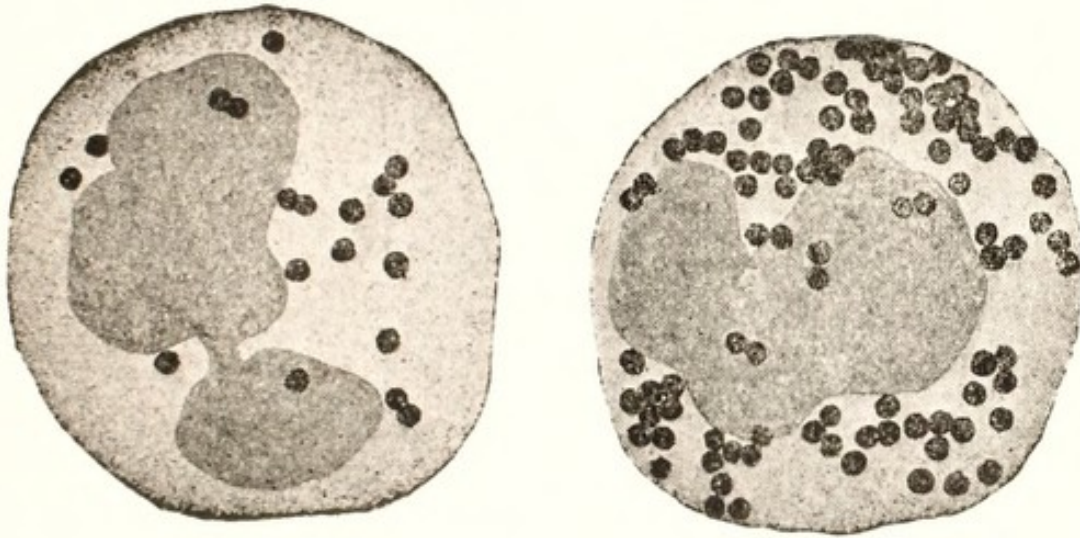


FIG. 15.—PHAGOCYTES AND VACCINES

This cut shows two phagocytes from animals infected with *staphylococcus pyogenes*—the common pus-forming bacterium. The animal from which the cell at the left was taken was untreated. The animal from which the right hand cell was taken had been treated with “vaccine” consisting of a culture of these organisms killed by heat. Many more bacteria have been taken up by the phagocyte of the vaccine treated animal.

bacteria thus used are called *vaccines* and the substances produced by the body cells under their influence are known as *opsonins*. This name is derived from a Latin word which means “I prepare food for.” The manufacture of

opsonins by the body cells under the inspiration of vaccines has been most effective in infections by the pyogenic cocci. Though called by the same name, these new "vaccines" have nothing to do with the vaccine lymph which is used to prevent small-pox.

It is generally believed to-day that most of the substances in the body fluids which kill and destroy bacteria are furnished in part at least by the leucocytes. So these doughty defenders of the cell republic reach marauding bacteria, not only when alive by personally swallowing them, but by setting free germ-killing stuff when they have succumbed.

Based upon this knowledge of the effective action of the leucocytes in setting free protective stuff, Dr. Hiss has proposed to secure leucocytes in quantity from the lower animals—the rabbit for example,—and to introduce an extract of these into the bodies of persons suffering from acute infections, thus reinforcing their capacity for resistance.

This method of treatment is still under investigation. But the reports of those who have applied it in a variety of human in-

fections seem to indicate that the extracts of alien leucocytes used in this way may be of great value.

The incitants of small-pox and hydrophobia are as yet unknown, though they are probably not bacteria. But we have methods of preventive inoculation in both of these serious diseases which are remarkably effective.

These methods both depend upon the gradual adaptation of the body cells to an infectious agent. At first material of slight virulence is used; then that which is more potent. Thus presently the body cells, without the acquirement of the disease by the individual, have become so fully adapted to the new conditions, that the body is protected from the disease altogether.

In small-pox the virus of diminished virulence is secured by passing it through the body of an insusceptible animal, the calf. Then, while it does not induce small-pox in man, it protects man from it.

In hydrophobia the unknown living infective agent, which is present in the nervous system of rabid animals, through the method of

Pasteur, is treated by drying the nerve tissue in the air, in which process its virulence steadily diminishes. Thus it is possible to get material of all grades of strength. So that if a person bitten by a mad dog be injected at first with a long-dried material, then day after day with that which has been dried for a shorter time, at length with no symptoms whatsoever to indicate that his cells have been responding to a powerful infective agent, he has acquired complete immunity or protection from the disease, which has not been permitted to develop.

The mortality from hydrophobia before the day of preventive inoculation was about sixteen per cent. Through this treatment it has been reduced to about two tenths of one per cent.

In the early days of our knowledge of bacteria, the highest hope was cherished that it would soon be possible to destroy bacteria in the body by disinfectants. But this hope soon faded, for it was found that any such substance strong enough to be effective would kill the body cells as soon as it would the bacteria.

But there is one infective disease—malaria, not induced by bacteria, but by microorganisms belonging among the protozoa, in which the early dream is realized. For in most cases quinine suffices to destroy the organism without damaging the man. Thus by quinine and mosquito screens and draining the swamps, this pest of many countries and neighborhoods may be effectively suppressed.

We have thus learned that there is an immunity to infection which races, species, and individuals naturally enjoy or may acquire by a successfully encountered attack of an infectious disease. We have seen that the body cells possess a marvellous power of adapting themselves to new adverse conditions, by the use, to new ends, of capacities by which the usual life is carried on. So when one recovered from diphtheria or typhoid fever is for a time immune, we know that this marks an adaptation of his cells to a new environment, evanescent it is true, but analogous with those adjustments by which in the long processes of evolution new traits were

fostered as plants and animals slowly rose to higher types.

But beyond this we have found out that we can secure an artificial cell adaptation by proxy in the horse, and through his cells, educated for the occasion, secure the precious juices which not only can confer immunity upon the well, but can save those already stricken. In these and many other ways which we have but glanced at in passing, we can reinforce to-day the subtle safeguards of the body against the minute incitors of infection.

If we compare our knowledge of infectious diseases to-day with that which was current twenty-five years ago, it is evident that an advance has taken place which is fairly revolutionary. Then we did not even know what caused most of the infections. The efforts to cure them were uncertain and ineffective, and preventive measures were largely futile. To-day we know what the causes of most of these diseases are, how the recuperative forces of the body meet them, in many instances what we can do to help these forces,

and finally how these scourges of mankind can be controlled by a little honest and intelligent cleanliness.

Now step by step as this knowledge has grown, it has been necessary to use the lower animals in studying the action of these new-found micro-organisms, and the ways to prevent their ravages. These animal experiments are always most carefully performed, anæsthetics being used whenever necessary, by the humane and self-sacrificing devotees to the advancement of knowledge. Without the free and untrammelled use of the lower animals for experimental purposes, children would still be suffering and dying by thousands from diphtheria each day, the world over, and the doctors would be helpless to save them or largely stop their sufferings. The pitiful victims of cerebro-spinal meningitis would still face a hopeless future. We should be back in the old age of helplessness towards most of the infectious maladies.

It is well for us all to realize this, because a number of persons, a part of whom are ignorant but well-meaning, a part ignorant and

malicious, are stirring about and endeavoring to interfere by legislation with the advancement of science through that research which involves the use of certain of the lower animals.

It is one of the duties which good citizenship lays upon the informed and the honest, to see to it that the crusade of short-sighted ignorance and falsehood, which its devotees name anti-vivisection, shall not be permitted to stay the progress and cloud the outlooks of beneficent research.



CHAPTER XVI

THE COMMON SOURCES OF BACTERIAL INFECTION

AS we glance back over the ground which we have traversed together, we see that the most common bacterial diseases which in this country we are apt to come in contact with, so far as they are definitely known to us, are colds, tuberculosis, typhoid fever, diphtheria, influenza, pneumonia, and the wound diseases or blood poisoning.

We have seen that in most of these diseases the infective agent is liable to spread from one individual to another, because it is not destroyed by disinfectants, or in some other way, as soon as possible after it is discharged from the diseased person.

We have seen that the most common ways in which the virulent bacteria are spread are by personal contact or by the food we eat,

the air we breathe, and the water we drink. If any of these necessities of life contain the living germs of these diseases, there is a liability of the infection of healthy or predisposed individuals.

The liability to acquire these diseases is always increased in direct proportion to the crowding together of the sick and the well under unsanitary conditions in large communities. This is not because filth and dirt are in themselves infectious, but because pathogenic bacteria are liable to become mingled with the rest. In other words, there is a simply filthy filth, and there is a pathogenic filth, and the two are very apt to go together.

No gas, however foul, no accumulation of dirt, no degree of malnutrition or misery or overcrowding can induce an infectious disease. It is always and everywhere some particular form of disease-producing germ which causes the trouble. The other influences bear largely upon the chances of incurring the disease, and often determine the severity of its course or its fatal ending, but they alone cannot cause it.

It is not the great and sweeping epidemics,

dramatic and frightful as they are, which carry off prematurely the largest number of people; but it is the bacterial diseases which we have constantly with us, and to which we have become so accustomed that we do not usually realize their vast importance, and against which systematic and persistent crusades on the part of the health authorities are only occasionally and fitfully undertaken.

Civilized communities have ceased to fear Asiatic cholera very much, because we have learned that it is easily suppressed by proper sanitation. The traditional ravages of the plague are possible only among the filthy in person and surroundings. Small-pox we do not now seriously dread, because immunity can be secured by a scratch upon the skin. Diphtheria and cerebro-spinal meningitis have largely lost their terrors since the discovery of the life-saving antitoxins. Hydrophobia is fully within our control.

But how is it with some of the less dramatic germ diseases which we have always with us, although we have known for many years how they can be largely prevented?

Malaria ravages large districts, because we do not drain the puddles and will not harden our hearts against the mosquito.

Typhoid fever claims its victims singly and in wholesale—more than thirty thousand die every year in the United States—chiefly because we are not yet ready to see that our sewage is disposed of elsewhere than in our drinking waters.

Tuberculosis, the king of the revels in this dance of death, ends a lingering illness in fully one hundred and fifty thousand persons annually in this country alone. And these multitudes perish prematurely because we do not insist upon the most obvious requirements of personal hygiene and the simplest details of public and private sanitation.

In fact, our science is far ahead of our practice, and it now rests largely with the people and the health officials whom they select to guard their interests to say whether or not in the next decade we shall enter into our birthright.

It is not difficult to suggest broadly the things which must be done if we are to profit as we may by the promise of preventive medi-

ciné. Honest hygiene must be taught in schools and colleges. Public-health officers must know more about sanitation than about politics, and there must be educational institutions where their special duties can be learned. An enlightened public sentiment must sustain them in their efforts to promote the general welfare, even though the individual may now and then be inconvenienced.

But when efficiency shall have been secured in the public-health administration, a large responsibility will still rest upon the citizen.

He can get clean food, pure water, and unpolluted air by asking for them and insisting that he have them. But he must insist, and he must be vigilant.

The danger of infection with disease-producing bacteria which we may encounter in the ordinary paths of life lurk, as we have seen, for the most part, either in food, or air, or water. Let us now look at these sources of danger a little more closely.

Food Infection

Milk. This is such an excellent food for

bacteria that though practically germ-free when it comes from the cow, before it reaches the consumer it may, if not kept cool, contain millions of germs in a single spoonful.

It has been found that milk which contains a great many bacteria, though these may not be of a kind which ordinarily induce disease, in infants and young children may cause serious even fatal digestive disturbances. But well-known disease-inducing bacteria often get into milk. Tubercle bacilli may come from the tuberculous cow. Typhoid bacilli may get into the milk in careless handling directly or indirectly from typhoid-fever cases or from "typhoid carriers," or by the use of sewage-polluted water in washing the cans; or flies in their wanderings may contaminate it. Similarly, the bacteria of diphtheria or the unknown organism of scarlatina are known not infrequently to be conveyed in milk.

All of these sources of danger should be, and in many communities are in a measure, controlled by the public-health authorities. Much has been done to secure safety by im-

proved sanitation of the dairies, and to-day in many places, by paying a little more, the consumer may get milk which comes from carefully supervised dairies and intelligently controlled dealers. This is called *certified* milk.

It is possible by the boiling of milk, or by properly exposing it to a lower temperature for a considerable time, called pasteurizing, to destroy the dangerous germs. If the householder is not averse to taking a little extra trouble, a domestic pasteurizer may be used on the kitchen range for each day's supply of milk and cream. Then, he may go about his business and worry no more about milk. The Freeman pasteurizer is well adapted to household use and requires no special skill in management.

Meat and Vegetables. The meat of tuberculous cattle is not likely in civilized communities to be a serious source of evil, because official inspection is widely practised and few people eat uncooked meat.

As the germs of various diseases may be floating in the air in densely populated districts, and are often present in farm and

market garden manures, all fruit, vegetables, and salads should be thoroughly washed before they are eaten. If such articles are to be cooked, though not so vital a matter, washing is at least a contribution to decency. The exposure of such foods upon the sidewalk in cities, as is so often done, is a filthy practice, and this alone should decide the householder to dispense with the supplies of any dealer who persists in it.

There is no doubt that the germs of typhoid fever, and when it is prevalent those of Asiatic cholera, are conveyed by food contaminated by the discharges of sick persons or the activities of flies. This, of course, is most frequent among the poorer people in towns whose market stalls are in the gutter, and whose living-rooms, alike for sick and well, must serve at once as kitchen, dining-room, garbage reservoir, and bed-chamber. But among those more fortunately circumstanced, the conveyance of the diphtheria and the typhoid germs on uncleansed spoons, dishes, etc., as well as through contaminated food, is of no infrequent occurrence.

The general recognition of the importance of sanitation has brought to the front a host of harpies who worry the people with foolish tales of bacterial dangers in order to exploit alleged disinfectants.

Chemical disinfectants are seldom needed in the household regime, except for the excreta of victims of infectious disease. Then the counsel of the doctor, not the fatuities of the advertisers, should guide the selection. For general purposes, soap, hot water, and proper scrubbing are the best cleansers.

It should be borne in mind that bad odors in the habitations and assembly places of mankind are to be prevented, not concealed. The dribbling, at considerable expense, of aromatic oils and solutions about toilet-rooms—masking but not removing the sources and risks of bad odors—is a mark of one of the more common triumphs of predatory misinformation, over the ignorance of well-meaning householders and managers.



CHAPTER XVII

WATER AND ICE AS SOURCES OF INFECTION

Contaminated Water

WE have seen in another part of this book that natural surface waters always contain considerable numbers of living bacteria of various kinds, which are growing and proliferating there, and no doubt actually purifying the water in a certain way by feeding upon and removing from it organic material which has collected or been dissolved. Now these bacteria in moderate numbers, under ordinary conditions, are not at all harmful to the consumer of the water for drinking or culinary purposes.

But, on the other hand, if the water becomes stagnant and the ordinarily harmless bacteria collect in very large numbers, it has

been shown by bitter experience that the use of the water may give rise to serious acute disorders of the digestive system. Cholera morbus and the so-called winter cholera are apparently sometimes caused in this way. Young children are especially susceptible to the bad influences of such water, and the boiling of it, or the change of supply, has repeatedly been found sufficient to stop attacks of cholera infantum or the summer diarrhoea of young children.

On the whole, however, the bacteria which water naturally contains as it is found in lakes, running streams, and good springs are usually quite harmless.

The frequent real and serious dangers from impure drinking-water do not lie in the bacteria which naturally occur there at all, but in those which get into it from outside, through pollution by the waste from animals and human beings, and especially from human beings who are the victims of some bacterial disease.

Polluted water may convey the bacteria which cause Asiatic cholera, and the same is

true for diphtheria or the wound diseases, and doubtless many others, but the spread of these latter diseases in this way is no doubt quite infrequent.

It is typhoid fever, whose germs, of all those which cause disease, are, so far as we now know, most apt to be spread by polluted water. The discharges from persons ill of typhoid fever, thrown without disinfection into the vaults of country or village out-houses—which, in an appalling number of cases, are in direct communication, through underground channels, with the wells, or with springs from which the farmer supplies the family or guests,—may pass, with but a very moderate dilution into the digestive tracts of the unsuspecting victim. It is ignorance, and carelessness, not Fate which, under these conditions, sets up an epidemic of typhoid fever.

The water supplies of large towns come, for the most part, either from large rivers, or lakes, or artificial reservoirs along the course of smaller streams, or from artificial wells, which, piercing the upper strata, gain access

to the deep underlying collections. Now in the surface water supplies, as from rivers or from lakes, man is his own worst enemy, because the most serious dangers from impure waters arise from its contamination with human waste.

Many great water supplies, which, under ordinary conditions, are good, are constantly liable to become sources of danger, because the sewage from dwellings is discharged, if not into them, still, so near to them that it may now and then enter, being washed in by rains or in some other way. This, under ordinary conditions, may, if the sewage be largely diluted in the reservoirs or streams, be simply disgusting and filthy, though not positively dangerous. But if, as is at any time liable to happen, typhoid-fever discharges in considerable quantity get into the waste-pipes and so into the water, the danger of the spread of this disease becomes of great importance.

Another great source of water supply for large cities and towns is the rivers on whose banks they are built. The water is usually taken at a point some distance above the

town, so as to avoid the sewage of the town itself, which, as a rule, is allowed to escape directly into it. But in almost all cases, in thickly settled countries, there are other towns on these streams above the points at which the water is taken, polluting it with their sewage. Now so prevalent is typhoid fever all over the civilized world that the sewage of every large town is liable to contain greater or less numbers of living typhoid bacilli.

In older countries where the sanitary dangers which always grow with the increase and massing together of the people have been longer observed and more definitely recognized than in our own, legal enactments have long been in force to prevent the pollution of streams which might be sources of water supply of towns. But still large cities have found it necessary to further protect themselves against disease-producing organisms and against filth, by the maintenance of filtering systems on a large scale, by which the dangerous elements of a contaminated water may be largely or entirely removed.

We should not forget that contaminated water always tends to purify itself in certain ways when exposed to the air in large volumes, as in lakes or running streams. Nor should we lose sight of the fact that a moderate amount of sewage, when poured into a large volume of water, becomes so considerably diluted, that its dangerous elements are much less numerous in any given glass or volume of water than in sewage itself. But such considerations can afford but little real consolation to those who find themselves forced to drink sewage, even though it be very largely diluted. The sewage may contain one hundred thousand typhoid germs to one teacupful, while the diluted mixture has in it not more than one to the same volume. But it should never be forgotten that the one germ is capable of multiplying in the human body to an enormous extent, and for this reason, in the living bacterial poison dilution is of much less significance than in ordinary poisons which are not alive and self-propagating.

The fact is, that in view of all that we have seen of the nature of bacteria and their dis-

ease-producing powers, sewage-polluted water from wells, or springs, or rivers, or lakes, ought not to be used for drinking and culinary purposes without some system of purification which is demonstrably efficient.

The new methods of bacterial analysis of water, which have been described in the earlier pages of this book, can give a clue sometimes as to whether or not a given water has actually been polluted with sewage, or human or animal waste, and especially whether the modes of purification to which it has been subjected, either naturally or artificially, have actually been efficacious in removing the living germs. But intelligent inspection of the sources is usually better than any laboratory analysis in determining whether a water is improperly polluted.

It is thus evident that upon the intelligence, knowledge, and fidelity, of the authorities largely rests the responsibility of pure water supplies for cities and towns, and the householder is to a large degree at the mercy of these officials, so far as his protection against the acquirement of bacterial disease, especially

typhoid fever, is concerned. For it has been shown over and over again, by the most careful and elaborate experiments and examinations, that the small so-called faucet filters, and pretty much all the reservoir domestic filters, do not separate the bacteria from contaminated water in a reliable way. The water is often strained by them and so freed from its coarser floating particles, and then may appear quite clear and limpid, and some of the bacteria may be at first removed; but after a little while not only do these small filters let the invisible bacteria through their pores in large numbers, but they may actually afford breeding- and lurking-places for the living germs,—the disease-producing forms among the rest.

Filtration on a large scale in properly arranged systems appears to be the only reliable way of freeing contaminated water mechanically from its bacterial ingredients.

Boiling of water for half an hour will, however, kill the bacteria, and to this, in the last resort, the householder must have recourse to when the water supply is justly suspected

be causing and fostering disease. This purification of water by boiling may be done by the householder himself, or, if he can afford it, he may supply himself with the distilled and aërated water which is now furnished in many towns.

But, after all, when the facts about the dangers of a polluted water supply become generally known, it ought not to be necessary for the householder to adopt any domestic precautions against water infection in towns or cities. If politics, or private or corporate greed, or general ignorance or apathy stand in the way of sanitary reform, the outlook for the water consumer is indeed not encouraging. But even these obstacles in the way of comfortable existence have been and may again be set aside.

There are other ways, safer and more economical in the long run, of disposing of sewage than by running it into the reservoirs and water courses which are the inheritance of all the people. The common law, decency, and prudence all forbid it. Sooner or later, and the sooner the better, the protection of our

drinking-water sources and closely land-locked waters altogether will be secured. Then there will be a big drop in the tale of preventable disease.

Those who dwell in the country, and those who repair thither in the summer, should be very watchful of the water which comes from the ordinary wells. It is quite true that the water which soaks into the majority of wells in the country and in villages has been filtered, and more or less purified, as it passed through the soil and earth about the well. But in a great many cases the surface water runs directly into the well at the top. Washing is not infrequently done in its immediate vicinity, and the waste and dirty water runs directly, or with but little filtration, back into the common receptacle. The vaults of out-houses, barn-yards, and pigstyes are often in close proximity to the well, on establishments which in circulars and newspapers figure as country health resorts. And this is by no means true alone of those which are inexpensive and primitive, but almost equally so of many of the more fashionable and popular establishments.

Every person who goes or sends his family into the country in the summer, should personally inspect the drinking-water supply and assure himself that it is good. This is actually of far greater importance than the size of the rooms, the price of board, or the diversity of amusements, or any other of the score of things about which one so scrupulously inquires before laying out the summer campaign.

Wells ought to be cemented water-tight for from eight to twelve feet below the surface. They should rise several inches above the level of the ground, which should be cemented and made to slope away in all directions from the opening, so that drippings and surface water may be carried off to a distance of several feet before they soak into the ground.

It should always be borne in mind that the water of ordinary wells is simply surface water, which has filtered down through the soil, and collected in the reservoir which the well excavation makes, and that in closely populated regions the soil, which originally may have been efficient as a filter, may finally

become so filthy as not only no longer to cleanse the water, but to actually contaminate it as it percolates through.

It is difficult to lay down rules by which the safety of country and village wells may be judged. But a very moderate acquaintance with sanitary principles will usually guide one to a just opinion. The argument which the enquirer is most apt to encounter favoring the salubrity of a country or village well, is that the owners' fathers and grandfathers drank water from the well all their lives, and they and their families lived to a good old age. But the fact is frequently lost sight of that the slops and sewage of this long-lived race have usually been accumulating in the soil about the house, as the years have sped, and as their towns and villages have grown the stables and hog-pens have neared the ancestral roof-tree. In short, that the sanitary conditions have entirely changed. The fact is, that wells, as they exist in most villages, and on many farms in this country, are an abomination and a perpetual menace to the health and lives of those who use them.

Impure Ice

The use of ice in preserving food and for drinking purposes has become a very important factor in modern life, and a means of incalculable benefit to all classes of people.

It was formerly believed that freezing destroyed in large measure the impurities of water, and within certain limits this is true. But it has been found, as the result of a long series of careful experiments by numerous investigators, that those important contaminating elements in polluted water, the bacteria, may resist for long periods the influences of cold. Good ice is so clear and beautiful that it is difficult to believe that it may harbor among its crystals large numbers of even such tiny bodies as the bacteria, but this is nevertheless quite true.

It has been found that the ordinary domestic ice contains large numbers of bacteria.

It has been further found that that most dreaded form of bacteria, the typhoid bacillus, may remain for long periods living and virulent in solid ice blocks.

It follows directly from these simple but undeniable facts that the sources of our ice supply should be carefully scrutinized in the interests of the public health. But, unfortunately, under the influence of the old idea that water was thoroughly purified by freezing, it has become the general practice of many of the dealers to get their ice from almost any source, however unclean, which is near or accessible enough to the market to afford a profit.

However, the typhoid bacilli gradually die off in ice so that after several months it may have purified itself. While this is reassuring, it is not enough.

Ice should not be cut, at least when it is to be used for drinking purposes, from any source which would not be good if it were used for drinking unfrozen.

The dumping of city garbage in vacant lots or in the water in the vicinity of towns is one of those barbaric fly-breeding practices which strangely enough still widely prevails in spite of the fact that both efficient and cheap apparatus for burning it are well known and

employed by many of the more intelligent and cleanly communities. Thus the soil and the shores of streams and other bodies of water near towns are often polluted.

If sewage were everywhere systematically destroyed, instead of being permitted to run into and pollute the streams and lakes, which, from their size and situation, afford the natural water and ice supplies to towns in their vicinity, the problem, on which so much depends, of obtaining pure and safe water and ice would be much easier of solution.



CHAPTER XVIII

HAZARDS OF THE AIR

THE only way the air which we breathe can be infective, that is, can be the means of transmitting disease-inducing bacteria, is, under ordinary conditions, by carrying as dust the dried but living germs from some infected individual or animal along with other and less harmful dust. Thus it is that our recently won knowledge of bacteria and other minute organisms has brought a new significance into the problems of ventilation. Foul air we still know to be bad and capable of fostering serious susceptibility to disease, but the specific and most significant elements of positive danger are in the floating dust.

The possibility of taking infective bacteria into the nose, mouth, and lungs with the air out-of-doors, especially in large cities, is always with us. But ordinarily the dilution

of the dangerous elements by winds and air currents is so vast as to reduce greatly the chances of evil effects from swallowing or inhaling them. Still, in large towns, whose streets are not faithfully cared for, the probability of being obliged to pass through clouds of dust whenever one goes upon the streets, especially in the windy seasons, is very unpleasantly suggestive of danger, and more than suggestive of filth.

But after all, it is in living-rooms and in places of assembly that we must look for the most frequent sources of danger. Here the dusty air is undiluted, is swept round and round by interior currents, and breathed over and over again.

Among workers in very dusty trades such as indoor stone cutters, miners, and steel grinders, dust is a direct incitant of serious disease of the lungs. Under the ordinary conditions of life dust is rather a predisposing factor, making the lungs and body at large more susceptible than it should be, to the incursions of disease-inducing germs.

When much dust gets into the lungs the

phagocytes take it up as fast as they can and carry it along the lymph channels. Some of it is left in little cell masses called lymph nodules which are placed along the course of these channels. Some is carried along to the clusters of lymph-nodes at the base of the lungs. These lymph nodules and lymph-nodes are thus places of deposit for foreign things gathered by phagocytes. In these, too, as we have seen, the phagocytes complete their destruction of bacteria and various tissue fragments which they have gathered.

Now if these important way stations and places of final disposal become blocked up by excessive amounts of dust brought to them, the body is deprived of one of its important safeguards against infection.

How much of this sooty dust people sometimes accumulate in their lungs is seen in Plate XII. This figure is a copy of a photograph of a lung of a resident of a large city, who had spent several hours each day, for years, in public assembly places. The amount of black dust is deposited over the surface of the lung in the lymph nodules

spoken of above. The lymph-nodes at the root of the lung not shown in the picture were much enlarged and jet black.

While, as we have seen above, there is a certain hereditary predisposition to tuberculosis which is resident in the body cells themselves and of the exact nature of which we are quite ignorant, there is little doubt that one of the most important reasons why tuberculosis is apt to run in families is that children and relatives of consumptives are more liable than others to come in direct contact with the disease-producing germs, which have been thrown off from the bodies of their house-mates under conditions which permit of their transmission. This may take place through sneezing and coughing or by the drying of excretions and their conversion into dust. What has long been considered as hereditary transmission of tuberculosis is largely household infection.

Theatres and churches, especially the former, are apt, as is well known, to be altogether inadequately ventilated. The headache and malaise which are so prone to follow a visit

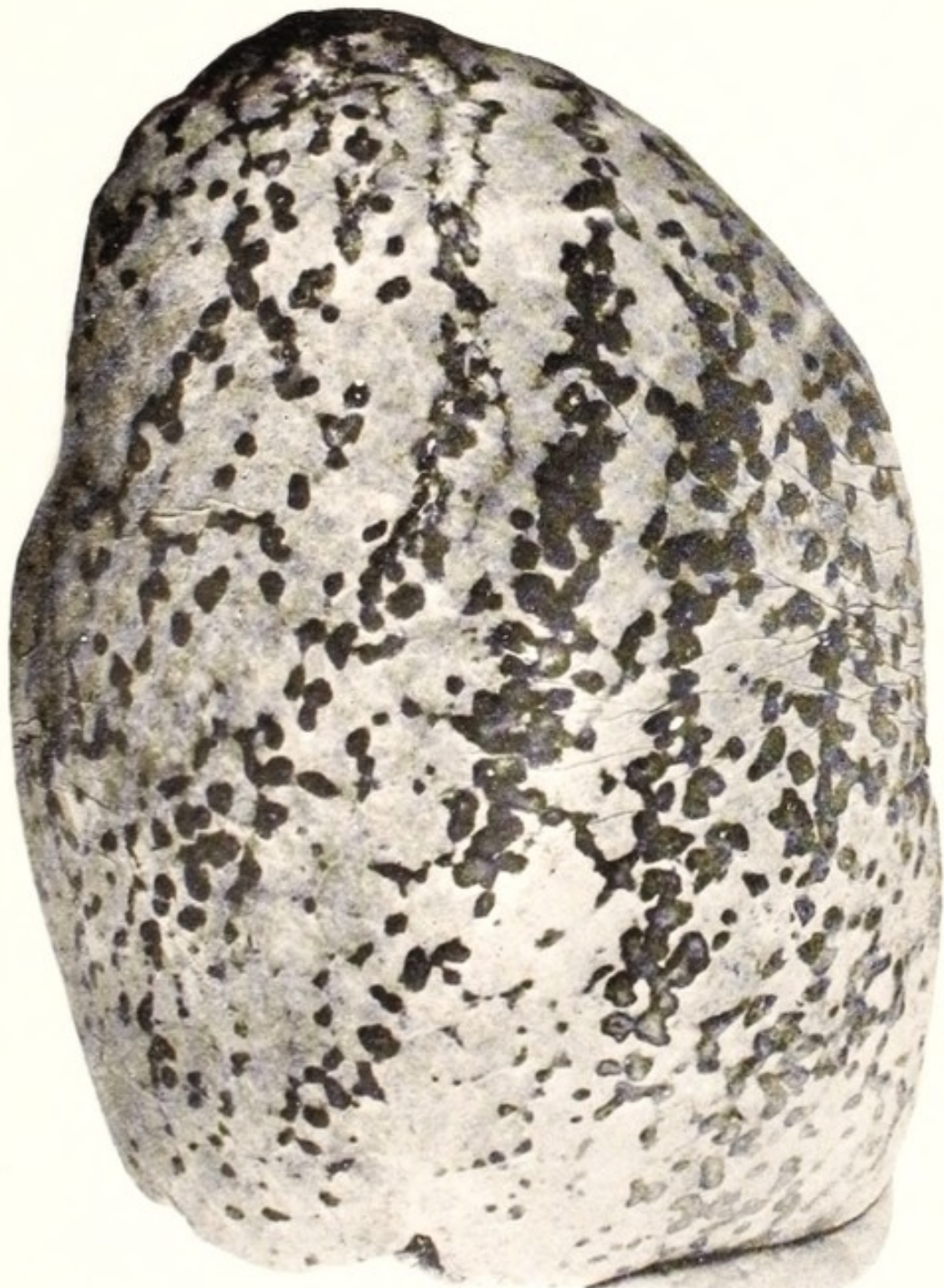


PLATE XII.—A DIRTY HUMAN LUNG

A slight depression at the upper part of this lung marks a small area of healed tuberculosis. The distribution of the pigment in streaks was caused by the pressure of the lung against the ribs.



to many of our theatres, are evidences of the high temperature, increasing moisture, and bad air which we are usually forced to breathe there; but the more subtle dangers here, as elsewhere, lurk in the dust which equally with the bad air is forced upon us.

No adequate means exist in most theatres for ridding the air of the dust. The best of them indeed are swept and "dusted" systematically and the larger particles of dirt collected and removed. But the floating dust is simply stirred up, and after settling is stirred again by the so-called duster, and so partially removed from the seats, but it settles again on the floors, to be again set in motion by the entering and retiring audience. It would be safe to say that the most effective method of removal of the floating dust from many of our popular theatres and churches is by its lodgment in the throats and lungs or on the clothing of the people who visit them.

Some of the newer and better theatres are furnished with improved and sufficient ventilating apparatus, some even have vacuum

cleaners but some of them have neither, and while in the majority we admire the chaste gilding and sumptuous upholstery of the interior, and complacently reflect that at length the law has forced builders of places of amusement to afford a measurable degree of security against being burned alive, those elements of danger in large assemblies, more important and more subtle than all the rest put together, namely, inadequate ventilation and cleaning, are seldom commented upon or thought about.

Recent studies have shown us that the earlier and still prevalent conceptions of the requirements of good ventilation were inexact. It is commonly thought that in unventilated assembly rooms where many persons are foregathered, the dullness, headache, and "dopey" feeling, which everybody has experienced, are due to lack of oxygen and to the accumulation in the air of carbonic acid gas and various human poisons which the people set free.

But in fact these all appear to be of secondary importance. It has been shown by most

elaborate and convincing experiments that the slow poisoning, which under these conditions we suffer, is self-poisoning, due to the high temperature and accumulated moisture of the air. These interfere with the necessary burning up of refuse products within the body and prevent the usual and continually necessary excretion through the lungs and the skin of poisonous stuff of our own making. If we cannot get rid of this in these ways we inevitably suffer.

It has been shown by an experiment with a man in a box, who is allowed to get self-poisoned in this way, that if the air be cooled and the moisture removed so that the lungs and skin may both give off their poison-laden vapors, the man at once freshens up, his headache passes and he is quite recovered without any more oxygen or any less carbonic acid in his miniature chamber.

Now this does n't mean that oxygen, and plenty of it, is n't necessary for the welfare of man, or that an excess of carbonic acid is not bad for him. But it does mean that some of the most striking bad effects of ill ventilated

places are due to agencies which the current principles of ventilation almost wholly ignore.

What science requires to-day is not only plenty of oxygen and not too much carbonic acid, but proper temperature and moisture of the air. If we add to these requirements freedom from floating dust, we shall have set down the least which should satisfy a lover of fresh air in his enforced thralldom to the petty, damaging, and increasing tyrannies of in-doors.

In dwelling-houses, the problem of ventilation is in many respects simpler than in large assembly rooms, because to a certain extent the householder is aware of the possibilities of dust infection, from the condition of health of the inmates, and can act accordingly. But even here, under ordinary conditions, there seems to be, from what we have learned about the bacteria, more reasons than we have before appreciated for securing adequate ventilation and cleaning.

The ordinary practice of occasionally stirring up the settled dust with a feather-duster should give place to the use of moist cloths or dry

cloths frequently shaken out-of-doors, so that the dust may be removed and not simply redistributed. This becomes the more important if any inmate of the house is suffering from one of the bacterial diseases.

In the interests of health the fitting of houses with simpler furniture or less heavy hangings and fixed carpets is greatly to be desired.

It is from human waste that the larger part of the infective stuff comes which we should avoid, and it is, most of all, in floating dust and the spray of uncouth sneezers that this passes from one to another.

If we could gradually wean ourselves, in public places at least, from the carpet, that storehouse of floating filth, sending up unseen, with every footfall, its clouds of often infectious dust, to irritate the delicate recesses of our lungs; if we might venture to suggest to the well-meaning but usually wholly uninstructed or wofully misinstructed delegates of Hygeia in our cars, offices, theatres, schools, churches, and homes, that dust is to be got rid of, not simply set astir by the feather-

duster, we could largely reduce those affections of the respiratory organs which are a most serious and a growing menace to our modern life in towns to-day.

In fact, the household and general procedure need be neither complex nor burdensome, which amply fulfils the conditions of cleanliness. But the cleanliness which modern sanitation requires cannot be secured without the exercise of informed intelligence.

The regulation of the sick-room, and its communication with the rest of the house, is a matter on which the advice of the physician should be sought. First and foremost should stand the systematic and careful destruction of the infectious material in all discharges of whatever sort from diseased persons, by burning or by the proper disinfecting solutions such as five per cent. carbolic acid. In this solution the discharges should be allowed to soak for several hours before they are thrown into the sewer or otherwise disposed of. As to the cleansing of rooms after their occupancy by persons who have suffered from bacterial diseases, directions should be

obtained from the physician or from the health authorities.

The danger of infection with the germ of tuberculosis through the air by unguarded sneezing and coughing, and by dust, is very widespread, because consumptive persons are often for long periods not confined to their houses, or rooms, or beds, but may be more or less active centres of infection by mingling with the well in all the ordinary walks of life. We have seen already by what comparatively simple means a large part of the danger of the spread of tuberculosis and diphtheria might be prevented.

The risk of dust infection from diphtheria, and probably from other somewhat similar diseases, such as measles and scarlet fever, is more apt to be limited to rooms or houses where the disease has occurred, because the victims of these diseases are usually sick enough to be confined to the house or bed. But there are, as all physicians know, frequently enough cases of these diseases in which the patients go about among their fellows throughout the whole course of the

illness, or at least for some time after it is fully established.

The possibility of infection from any of the diseases which we have been considering, through dust and the spray of sneezing and coughing, emphasizes the importance of breathing through the nose and keeping the mouth shut except when it is necessary to have it open.

Finally the outraged observer of contemporary manners is sometimes tempted to regret that the altruism of to-day may not sanction the maintenance of mediæval oubliettes, into which the spitter in unseemly places, the trailer of her skirts upon the streets, the ministers in public upon our sidewalks to the private exigencies of their dogs, might all be quietly dropped together.



CHAPTER XIX

A DANGEROUS NEIGHBOR

IT is not among lions and tigers, reptiles or snakes,—save possibly the Indian cobra, that we have to look for man's most destructive animal enemy. These mostly stay at home and mind their business. And if an unwary man now and then suffers from them, it is an even chance that it is his own fault.

But the house-fly—for with him this chapter chiefly deals—wanders about, and gets its objectionable person onto or into almost everything. It breeds chiefly in manure and garbage heaps. It revels in almost all those things which to the normal modern man seem dirty, filthy, and disgusting. Then it wanders over the food and persons of men,

women, and children whenever opportunity offers.

This is certainly bad enough, and the excreta which we euphemistically name fly-specks, mark the scope of its summer excursions. But the worst of it is, that the bacteria which are swarming in most of the stuff the house-fly eats and dabbles his feet and tongue in, are in large degree alive, after they have passed the department of his interior, and they stay long alive upon his feet.

Now when the house-fly feeds upon infective human excreta—as he does whenever he gets a chance,—the typhoid bacilli or the tubercle bacilli or the contemptible brood which incites dysentery and the protean summer ailments of both old and young, may be carried directly and in full virulence to the food and persons of the well.

It has been shown by hundreds of accurate scientific observations that the house-fly is the conveyor of infective stuff, especially of typhoid fever, but also of the other maladies which we have named.

If the fly which favors us with his addresses

has come, as is most likely the case, from a revel in simple filth, he is just a nuisance, if from infective filth, he is also a menace.

Flies are fond of milk, and they usually fall in. After this beauty bath in which a few odd thousands of living bacteria are transferred to the milk, the fly may scramble out. But most bacteria, among them the typhoid bacilli, grow excellently in milk. Thus again and again have typhoid epidemics started through the intervention of the domestic fly.

A very simple experiment will illustrate what happens when a house-fly with dirty feet walks over food stuff on which bacteria can grow. One of the Petri plates, which was described in an early chapter, was partly filled with warm nutrient gelatin in which bacteria flourish. When it cooled, a smooth, solid surface was formed. An unwary house-fly was caught and his legs and body were dipped into a dish of very dirty sewage water. He was pinched a little, to quell his flying ambitions, and set down upon the surface of the gelatin. Here he was permitted to wander about for a moment and then met his

destiny. The plate was covered and set in a warm place for three days. Wherever his feet touched the gelatin, and where the body dragged, the bacteria grew. The result is seen in Plate XIII. The track of the wandering fly is marked in colonies of living bacteria, many thousands in each.

Similar results follow the contamination of milk by dirty flies. So also foods which flies visit and fresh berries in city markets are planted with germs of varying potency.

It is from improperly cared for discharges of typhoid patients that the chief danger comes. In the country the unsanitary out-houses which disgrace the age and in the cities which discharge their sewage into adjoining waters, there is abundant opportunity for fatal contamination of food through the fly. So flagrant are the offences and so significant are the results, especially in connection with typhoid fever, that it has been suggested by a distinguished entomologist that this fly known to science as *Musca domestica* should henceforth be called the *Typhoid fly*.

But I suppose that there is something to be



PLATE XIII.—TRACKS OF A WANDERING "TYPHOID FLY"

See explanation in the text.



said in extenuation of the faults of any criminal, even in the world of insects. If flies could talk, and would, they might well respond to the indictment by calling the attention of *Homo sapiens* to the fact that it is *his* unsanitary manure heaps and garbage piles, which afford the defendant its breeding places. That the chief offence is in dispersing dangerous stuff which man, in defiance of sanitation and decency, spreads abroad. That screening the houses will largely keep the accused out anyway. The defence might well be summarized—"No careless man, no *typhoid* fly." At any rate if we bear this suggestion in mind, act upon it, and then kill all the household flies we can, the typhoid fever statistics will surely score a noteworthy measure of improvement.

There are many other insects which play man false in conveying to him various kinds of infectious plants and animals of the microscopic world. Among these the mosquito and ticks are the most important. But we have already said enough about these, and so need not further prolong this short indulgence in entomological muckraking.



CHAPTER XX

THE END OF THE STORY

SO important is the subject of the causation of disease by these minute organisms, and so full is this field of the promise of practical and far-reaching benefit to man, that large numbers of scientific workers all over the civilized world are eagerly and patiently devoting their time and skill to the study of bacteria.

Great care and technical facility are required to carry on successfully this kind of investigation, and it is not at all surprising, since we have known how to study bacteria for but a short time, that we should as yet know very little about many of the bacterial diseases, or that we should often be mistaken in our interpretations of what we do know.

There is the greatest temptation for workers

in this field to magnify the importance of their observations, or to claim as world-reforming discoveries the results of imperfect observation or misinterpreted facts.

But in spite of mistakes and misinterpretations, in spite of the runaway enthusiasms which now and again lead the disciples of the new light to ignore the solid groundwork of experience which was founded in the old, we are daily gaining new facts and more commanding points of view, and the science of medicine has entered upon a new and brilliant epoch in its history.

The mysterious veil which has for so long hung over some of the most widespread and terrible diseases, is gradually being drawn aside, and we now stand face to face with known and understood and no longer, for the most part, with mysterious and incomprehensible foes.

Forty years ago it would have seemed an idle tale had one said that he could cultivate at will in the laboratory the very living essence and causes of such diseases as consumption, typhoid fever, Asiatic cholera, diphtheria, and

more of the uncanny brood, and could study and manipulate them as the gardener does his larger plants, and from the knowledge thus gained plan new and efficient means for treating and preventing the diseases which they cause. But all this is strictly true to-day, as we have seen in our review of man's invisible foes and the ravages which they can cause.

And so at last we are at the end of our story, so far as in such simple and hurried fashion it can be told to-day. It is a story which in parts is full of disquieting and unpleasant revelations, of facts which at first sight seem to make life under modern conditions less simple and attractive, and Nature, less man's friend. But after all there are few things more disquieting and unpleasant and unfriendly, to most people, than are disease and death, and these, sooner or later, will thrust themselves into the attention of everybody, be he cognizant or not of the varied disregard of nature's laws which for the most part they follow.

It should not be forgotten by those who are disposed to close their eyes to the disagreeable

and malign influences which, in the guise of disease-producing bacteria so frequently surround them, that the rights of others, as well as their own mental ease, are at stake in this matter. One has the right, so far as he is himself concerned, to indulge in almost any dietetic uncleanness, or disregard of sanitary rule with which he may elect to be satisfied. But he has no right to expose himself unnecessarily to the acquirement of such diseases as will render him a source of either positive or possible danger to his fellow men.

Among all the myriads of invisible agencies which are ceaselessly working for man's weal, we have discovered a few which are his deadly foes. We have seen that if one looks at the matter intelligently, the means of largely avoiding the evil effects of these dangerous earth-neighbors of ours are comparatively simple and effective, if we do not hide our heads, or shirk, or waste our time in protestations and regrets.

The fact is that with the increasing complexities of modern life, especially in towns and cities, we are subjected to a great many

conditions which constantly threaten the welfare of our physical machinery. So that we are forced to pay attention to a host of threatening agencies which in earlier and simpler times could be safely ignored. This is a part of the price which we must pay for what we are pleased to call modern civilization.

It should not be forgotten that underlying all the protective measures which have been devised by science against infectious maladies is the living body machine which each of us controls for himself. If through the various phases of unwholesome living so largely in evidence to-day, the machine is lacking in vigor, then by so much are the chances of recovery lessened when the shadow of disease falls across our path.

Not too much work nor too much play; not too much food and drink—but enough; good air and intelligent cleanliness in houses, assembly places, and public conveyances—if these conditions be fulfilled in such way and measure as the hygiene and sanitation of the day demand, we shall go far to establish our birthright to threescore years and ten.

And our immunity to infectious disease, whether we brought it into the world with us, or achieve it under the ministrations of the physicians, will most closely confirm the promise of science.

There are many of the uncanny and disagreeable things of life from which it were better that most of us turned away our eyes. But the avoidance of some of those forms of illness, whose causes have been considered in this little book, is so closely dependent upon a general knowledge of their nature that the offence of unpleasant revelations may, it is hoped, be forgiven by the reader in view of the ultimate and universal good which these lines have been penned to foster.



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