A BACTERIAL LABORATORY.

GLIMPSES OF THE BACTERIA.

BY T. MITCHELL PRUDDEN, M.D.

A MYSTERIOUS potency, which we call life, stole in upon the earth in the primeval silences, and has lingered on age after age as changeless and inscrutable as its Creator. Life is always associated with a particular form of matter called protoplasm, and has been transmitted from one being to another, high or low, in an unbroken series since it first appeared. But, so far as we know, it has always resided, as it does to-day, in little masses of protoplasm called cells.

In the higher forms of animals large numbers of co-ordinated cell communities are grouped together to form an individual capable of varied and complex powers, while in the lowest plants a single cell fosters the spark which but feebly suggests the wonderful capacities of higher types.

We know that protoplasm is an albuminoid substance, and that it looks very much alike in cells which may develop into one of the higher animals, or in those which remain in the lowly elementary condition which probably belonged to the earliest types upon the earth. Hence the indefiniteness of our attempts to characterize and explain its varied forms. This protoplasm has more than once been found at the storm centre of controversial vortices, because just here the material and the immaterial seem to meet.

A gentleman just returned from a scientific *séance* is said to have remarked that, so far as he could make it out, protoplasm appeared to be some new kind of arrow-root, a belief in which did not necessarily imply incredulity as to the inspiration of the Scriptures.

We analyze it, and find what elemental substances combine to give it form, we watch the things it does under the inspiration of the life forces, and these varied observations we get together and write down and call it a discourse upon life, or biology. But when in the last chapter we try to make plain to ourselves or to others what it is, after all, which makes this particular form of matter called protoplasm alone fitted for the residence of the life powers, when we try to picture the nature and origin of the inspiring agencies, we find that, like Omar, we

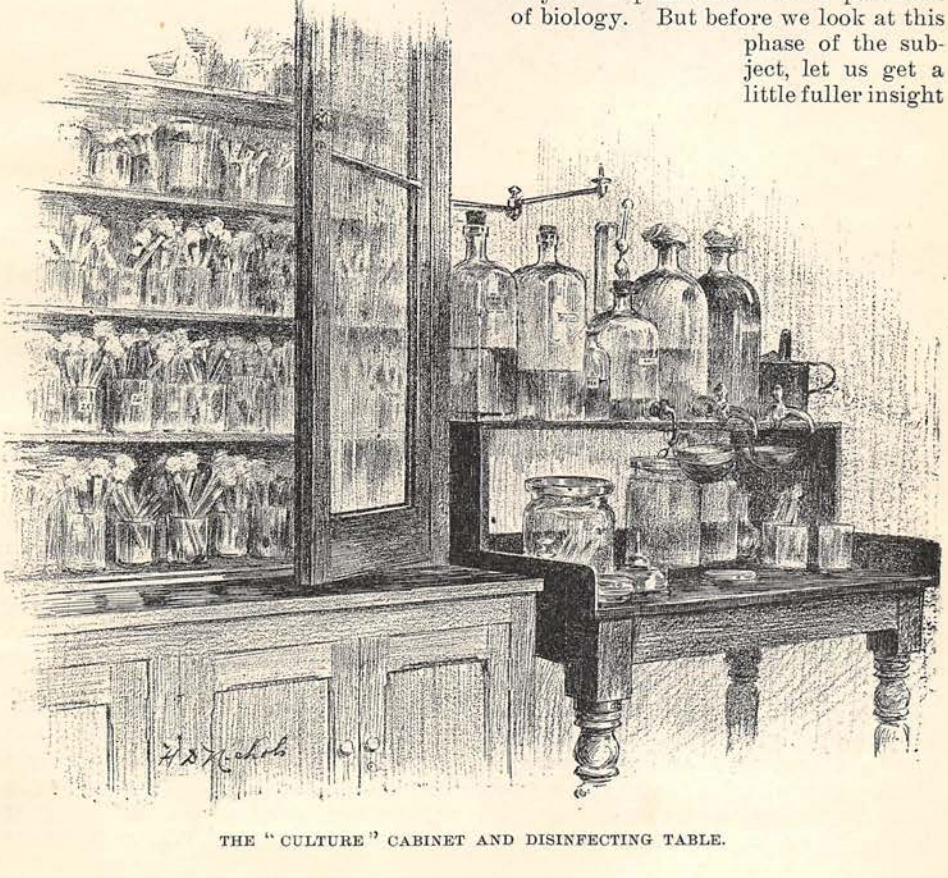
"have heard great argument
About it and about, but evermore
Came out by the same door wherein I went."

But while baffled in this supreme quest, it has come to pass in these later years that pathways entered upon in pursuit of the mystery of life have led many explorers by different and devious ways into a new invisible world of living things, at once so vast and so minute, so useful and so deadly, that the dawn of a new era in the science of life seems just at hand.

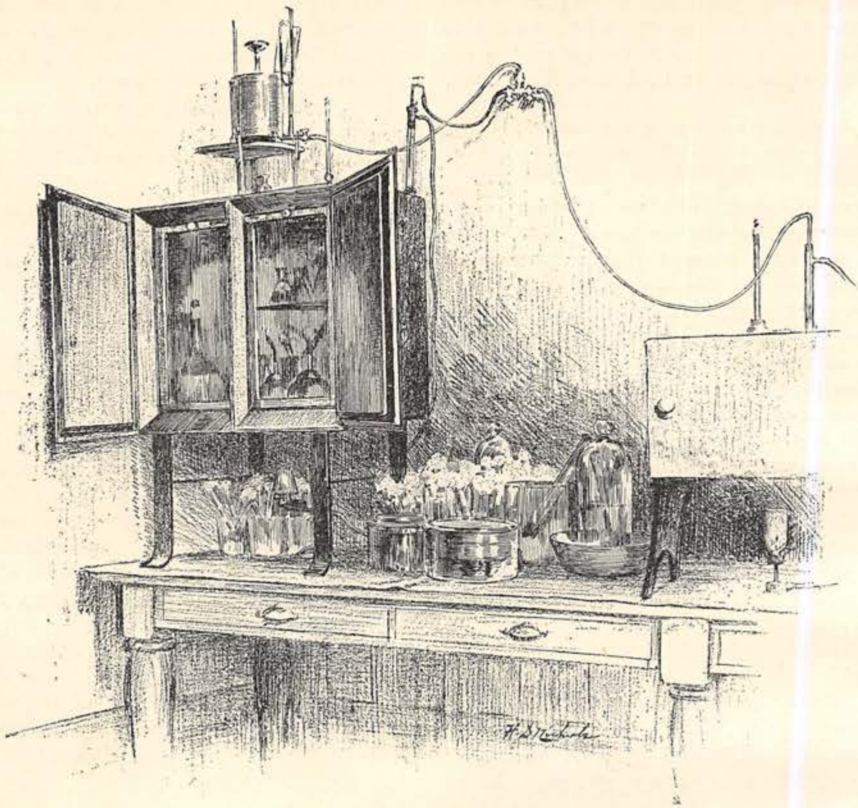
We have fancied that when the catalogues of visible animals and plants were written, when their varied habits and powers and origins were made plain, and when the record of the rocks had been read off and developed into a world history, we should be masters of the situation, and might even find time to carry on the often projected flirtations with the denizens of some other planet.

But gradually we have been taken into the confidence of some of the tired-eyed workers, who have for a good while been peering into the domain of the invisible, and are now ready to tell us that in earth and air and water are tiny beings innumerable, which, for weal or woe, have a power over all other living things so great and so far-reaching that we cannot yet even fairly conjecture toward what vantage-ground of knowledge and insight and well-being this new life lore is leading us.

Studies on the minute forms of life have been going on for several years, and a great deal of interesting and useful knowledge had been accumulated about them before the new technique devised and elaborated by Dr. Robert Koch within the present decade gave a new impulse to the work, and caused it to rapidly develop into a distinct department of biology. But before we look at this phase of the subject, let us get a little fuller insight



THE "CULTURE" CABINET AND DISINFECTING TABLE.



A WARM CORNER OF THE LABORATORY, WITH THERMOSTATS AND CULTURE TUBES.

into the character and relationships of these minute beings.

Far down in the scale of plant life—let it be distinctly understood that we are primarily concerned in this paper not with animals, but only with lowly plants—is a certain great group, whose individuals are spoken of in a general way as micro-organisms or microbes or germs. So small are they all that they are never seen as individuals by the unaided vision. It is only when they are growing in masses that they may be thus seen.

One great family of the group of micro-organs is called "yeasts," and when the grocer sends in to the cook a little square soft cake of yeast wrapped in tin-foil to keep it clean and moist, he acts as a connecting link between biological science and commerce and domestic life. The commercial value of one single yeast plant may be estimated on the basis that the single yeast cake, costing its consumer one cent, may contain many hundred millions of the single plants.

When these yeast plants, well distributed through the dough, are set in a warm place they begin to grow, and in order to grow they must consume food. Now the flour and salt and water in the dough are very choice viands for these little plants, and as they feed they tear these substances asunder where they lie, assimilating some elements under the influence of the life forces, and setting free, among other things, carbonic-acid gas. This occupies more space than did the compound of which it formed a part before it came under the resistless influence of the living plant cell. And so the bread "rises," and becomes light and porous: a happy result for us, though the poor yeast plants are fattened but to die, for at the right moment off goes the whole mass to the oven, where their myriad budding lives are soon extinguished. Thus when we eat the bread, we eat the myriads of cell fragments which made up the wheat or rye or barley of the flour, as well as the yeast cells themselves, and call it good. This is one of the best forms of food, and here, as in almost all our foods, the man, himself a vast aggregate of cells, assimilates the ruins of other cells, both of animals and plants.

There is a whole great and important series of manufactures dependent upon the life processes of different species of yeast plants analogous to those which we have reviewed in the bread. Beer-making and many other fermentations rest upon these life powers of the micro-organisms called yeasts. Where the various species came from originally it would be useless to speculate. What special purpose the beer yeast, for example, served in the economy of nature before the dawn of the Beer Age, who shall say?

There is another great group of micro-organisms very wide-spread in nature which we call "moulds." Not so useful in general as are the yeasts, and sometimes, but not often, directly harmful to man, they very frequently prey upon and destroy as blights higher forms of plants which man cultivates for his uses. When growing in masses, the appearance of moulds is familiar to everybody who has allowed pastry to grow stale in damp places.

The scope of this paper does not permit us to linger longer upon these families of lowly plants, the yeasts and moulds, about which, however, a good deal of very interesting lore has gathered.

Now at last we are face to face with our subject — another group of lowliest, tiniest plants, closely allied to the fungi; they are also micro-organisms or microbes or germs, but their particular family name is bacteria. An individual is called a bacterium; collectively they are bacteria.

It would seem as if here, if ever, we must come upon the secret of life origin in the study of these minutest of living things, the bacteria, made up as they are of single cells so simple in structure as to be almost completely represented by lines and dots, but endowed with such limitless powers of reproduction as to fairly shame the multiplication table.

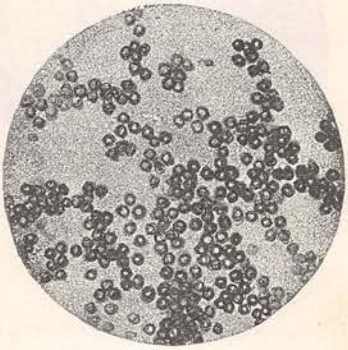
'Way down on the border-land of life lie these elemental organisms, so close to the edge of that chasm, deep as eternity, which divides the living from the non-living that it has now and again seemed to workers in this field that surely some stray germ had bridged the abyss, and sprung unancestored into life before his very eyes. But that pet nursling of so many an enthusiast in times gone by, spontaneous generation, has always been buried in neglect at last with this unvarying epitaph: Imperfect Observation.

Our systematic knowledge of the bacteria is still so meagre, so many species and doubtless so many families of them have never yet come into the range of human vision, and our glimpses of their life powers have been so fragmentary, that as yet we can only try to bring a little temporary order out of the chaos by grouping them according to their shapes.

We find, when we muster all the forms which have as yet been seen, that they all fall into one of three classes: spheroidal, rod-like, or spiral.

Further subdivisions of these classes have been made, and generic and specific names attached to many hundreds of forms; but over these details we need not linger now. How they look and what they do is here of more importance than what we call them.

Although with the ordinary microscopic powers the bacteria look like little balls or straight or spiral rods, we find, when

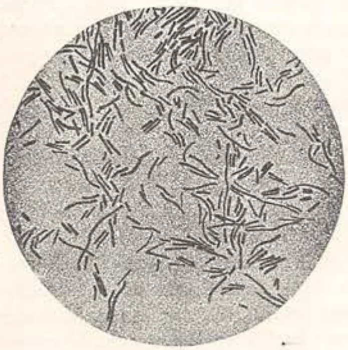


SPHEROIDAL BACTERIA (MICROCOCCI).
Cultivated from air. Magnified about 1000 times.

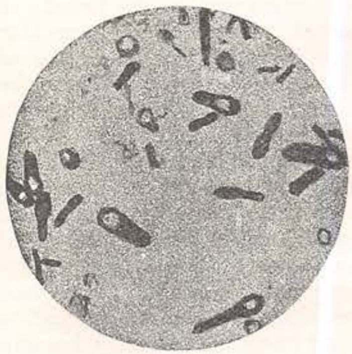
we use the most powerful and perfect lenses, that they consist of a minute mass of granular protoplasm surrounded by a thin structureless membrane.

When we put them under favorable conditions for growth, and give them food enough, they may be seen to divide across the middle, each portion soon becoming larger and again dividing, so that it has been calculated that a single germ, if kept under favorable conditions, might at the end of two days have added to the number of the world's living beings 281,500,000,000 new individual bacteria. In fact, if this sort of thing went on for a few weeks unhindered there would be very little room left on the earth's surface for any other forms of life, and pretty much all the carbon, hydrogen, oxygen, and nitrogen which is available for life purposes in the world would be used up. There would be a corner in life stuff, and even the master, man, would be forced to the wall, and become the victim of his insatiable fellow-worlder, the bacterium. But, as it happens, this sort of thing does not go on; the food grows scanty; or the temperature becomes unfavorable; or the sun shines hot—and the sun is a sore enemy of your growing bacterium; or, as it grows and feeds, the germ gives off various chemical substances which often soon poison itself, or its fellows, or both together. So the proportion is preserved by such a fine balance of the natural forces that, prolific as they are, the bacteria in the long-run are held closely within bounds the world over.

Indeed, life goes hard with many forms, and were it not for a very curious provision for the preservation of the species under adverse conditions, it is likely that many species would soon die out.



ROD-SHAPED BACTERIA (BACILLI).
Cultivated from water. Magnified about 1000 times.



ROD-SHAPED BACTERIA (BACILLI).
Developing spores.

BACILLI GROWING IN CHAINS.
Magnified about 1000 times.

SPIRAL-SHAPED BACTERIA.
Magnified about 1000 times.

It is found that when the conditions become too unfavorable for the continuance of life in some bacteria, a portion of the protoplasm sequesters itself in one end of the germ, and surrounds itself with a dense resistant envelope. This is called a spore. The old shell falls away, and this spore is now capable of resisting such vicissitudes of temperature and drying and fasting as would have destroyed it in its other form. Restore the spore, however, to favorable surroundings, and it bursts its protecting shell and emerges a thin-skinned and vulnerable, but an active and perhaps a triumphant germ.

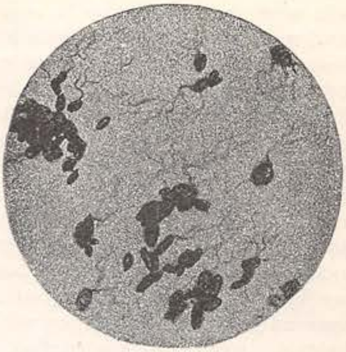
Some forms surround themselves with a soft, slimy pellicle called a capsule. When the bacteria, as they grow, divide and subdivide, the new individuals thus formed often cling together, and so form threads or chains or little heaps.

Many of the bacteria are capable of rapid progressive movement when floating in fluids, induced by little hair-like prolongations at their ends; many are wholly passive. All of them, so far as we know, have the power, in nourishing themselves, of tearing asunder other forms of matter, assimilating a part of it in new combinations in their own bodies, and setting free the rest. These chemical substances which are set free by living, growing bacteria are of the most diverse characters. They may be acid or alkaline, aromatic or bad-smelling; usually they are harmless, but sometimes are very injurious to man.

Some forms of bacteria, when growing in large masses, form brilliant coloring materials out of the ruins of the substances on which they feed. Some are phosphorescent, and when massed together you can read by the light which they emit. Some forms are easily killed; some are very invulnerable.

The soil forms the great living and lurking place of the more common forms, and from this they are spread far and wide in the air as part of the dust, or are washed off into the surface and other waters.

The life history of many of the species of bacteria is already very well known to us, while whole groups are almost wholly unstudied. This much has been well established, that there are some species which are quite indispensable to the higher forms of life in this world, because it is they which tear dead organic matter to pieces, and fit it to be taken up by higher plants, and worked over into food for men and animals. A piece of meat or any other organic matter would remain unchanged indefinitely if shut up so that no living bacteria could come in contact with it. Under ordinary conditions, however, the bacteria do gain access to them, and then ensue putrefaction and finally a total destruction, that is, a total change into other forms of matter. The bacteria are thus the great scavengers of the earth.



MOBILE BACTERIA WITH CILIA.

It is difficult to conceive that all these curious doings, all these far-reaching accomplishments, should be carried on by organisms so small that full a thousand of them, if mustered abreast, could pass through the hole pierced in a paper by a fine sewing needle and never touch the sides.

After these hurried glimpses at the curious things which people this realm of the invisible, I will ask my reader to visit the laboratory with me, and learn what he may about the devices which science makes use of to lure these beings into sight, and how we handle things unseen.

My visitor must lay off his over-garment and wipe the germ-laden dust of the outer world from his feet before he will be admitted to a precinct which, before all other earthly places, must be absolutely clean. The very air which is sent into the room from the ventilating fans is filtered through cotton to separate as fully as may be the floating dust. Walls and floors, both smooth, are frequently scoured with fluids which are deadly to peripatetic germs. Robed in a smooth-surfaced black gown is the bacteriologist—this arbiter of the fortunes of whole races of living things—not at the dictate of fashion, but because at the muster of these invisible cohorts he must let into the parade no chance enemy which might have been concealed upon his usual garments.

We might as well open at once the doors of a broad-shelved cupboard which stands at one side of the room, and show the visitors our bacterial garden. If we could number the individual plants which are growing on any one of the shelves of this small cabinet, we should no doubt have enough, were we disposed to be so generous, and were the suggested beneficiaries acquiescent, to give every one of the earth's inhabitants at least a million of the bacterial plants, and have enough left over to similarly endow every one who is to be born for the next ten thousand years.

What you see is a number of rows of common tumblers, in each of which are standing several glass tubes plugged at the mouth with a wad of cotton batting. At the bottom of each tube you see a transparent jelly-like substance which is our bacterial soil. On the surface or in the depth of this nutrient jelly you see variously colored pasty-looking pellicles or masses, which are the bacteria, plainly visible now, because they are piled up together just as they grow in such colossal numbers.

Some of the species have made the jelly fluid as they grew, and are floating in the tiny pool. Some of them are themselves colored variously; some have given color to the jelly in which they were planted. The names of the various species, so far as they have been described, are written on a label at the top of the tube. You may take out these tubes and look at their contents more closely if you wish. The cotton plug at the mouth of the tube will prevent all access to the germ plants of germs which may be floating in the air outside, and equally will prevent anything inside the tube from coming out. You will see that many of the tubes are labelled "BACILLUS"; that means a little rod, and this is the generic name of a very large and important group of bacteria having this shape. This particular one is called *Bacillus fluorescens*, because, as you see, it imparts to the jelly in which it is growing a beautiful greenish fluorescence.

Here is a tube marked "MICROCOCCUS"; that is another generic name applied to a large group of spheroidal bacteria, and this particular one is called *Micrococcus cinnabareus*, because when it grows in a mass, the mass has a deep cinnabar red color. These must serve as examples of the appearances and names of bacteria as they are seen growing in a laboratory collection.

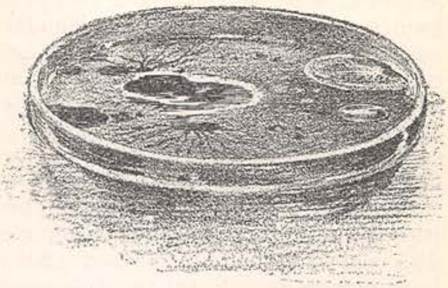
I see that my visitor's eyes are wandering to a shelf on whose tubes are seen such ominous names as pneumonia, tuberculosis, typhoid, tetanus, diphtheria, etc., and that as he reads them he steps back from the shelves. They are safe while they are there, however, perfectly so, those germs which cause these dread diseases, and I shall have something to say about them presently. Close beside this germ cabinet one sees a row of large jars containing fluids most deadly to all forms of germs, carbolic acid, corrosive sublimate, etc.—germicides we call them. All kinds of living germs which we have finished studying are deluged with and soaked in these solutions for some hours before they are permitted to leave the laboratory, and usually before they are removed from their cotton-sealed glass prison tubes. Now I should like to show you how we capture these germs, invisible in the earth and air and water, or on or in the bodies of men and animals, and how we get them finally growing here in tubes, each species by itself.

The first thing which a worker in this fascinating domain of science has to acquire, strange to many as the juxtaposition may appear, is faith, and perhaps faith and science more often go together than some people think. In the first place, the worker has to be certain that all the apparatus which he uses, the flasks and dishes and tubes and needles and forceps, are absolutely clean—not clean in the ordinary visible, but in the bacterial sense. For the bacteriologist that thing is alone clean which is wholly free from any form of living germs, and as these everywhere-floating and everywhere-lodging germs are totally invisible, he must at the outset treat all his utensils as if he knew they were covered with living things. For him everything is regarded as guilty until he has so treated it that he knows it must be now, at any rate, innocent—of germs. This treatment is called sterilization, and so he bakes and roasts and boils his apparatus, and all his bacterial food before he begins to work with it.

I need not describe in detail how the artificial bacterial foods are prepared, as this would lead us far afield. Suffice it to say that before we are ready to go hunting or fishing, whichever you like, for bacteria, we have a number of cotton-plugged tubes and flasks partly filled with the nutrient jelly, which is yellowish and transparent and solid, or with clear beef tea, or with boiled milk, or with little strips of boiled potatoes. These form the standard stock of our bacterial larder.

The average bacterium, common as he

may be, and getting along very comfortably in the state of nature in his own chosen haunts on very little food of all sorts, or on almost no food of any sort, is apt to be very dainty when his condition in life changes and he becomes the pet of the bacteriologist. He would apparently feed heartily on almost any sort of nasty stuff before, but now his beef tea must be just so alkaline, or he will pout and grow but little; if it is fairly acid, he refuses to grow at all. New potatoes are too fresh for his poor stomach, and must be seasoned for a few months before many of the clan will even look at them. Altogether it is not an easy life which these "beggarly atomies" lead the bacteriologist, who, as nurse and caterer, is often at his wits' end to know what is the matter with his sulky nurslings.



A "PLATE CULTURE" OF WATER,
Showing the size and number of "colonies" which have developed at the end of the third day. Some of them have fluidified the nutrient gelatine, forming tiny pools.

Suppose first we go a-fishing. Here is a glass of perfectly clear sparkling water, fresh from the pipes by which it was brought straight from the country hills. We can see nothing in it, and we might search drop after drop with the most powerful lenses, and find absolutely nothing but water. Here is where the faith comes in; or perhaps, after all, it is knowledge, if we have worked long in the field. We first melt a tube of gelatine, mix with it a small measured quantity of our water, say half a thimbleful, pour the whole perfectly transparent fluid mass into a flat-bottomed shallow glass dish or plate, and quickly cover it. This is called a "plate culture." In a short time the gelatine has again solidified, and any invisible germs, if such there were in the portion of water which we used, are closely surrounded and held fast by the solid nutrient wall. Now such germs as thrive on this sort of food—and that is a large proportion of the more common forms—will presently begin to grow, feeding on the walls of their prison-house.

This is not one of those operations which are finished while you wait, however, for a great many hundreds or thousands of new young germs must grow before you can begin to see anything at all in the clear gelatine. But if you set aside the dish in a warm place, after twenty-four or forty-eight hours you will see tiny points scattered through the gelatine, which we call "colonies." Each colony is made up of the progeny of the imprisoned aqueous ancestor. Presently the colonies get so large that, either with the naked eye or under a low power of the microscope, you can see their appearances, and make out with ease the differences of growth which characterize different species. Some of the colonies grow faster than others, some are sharp-edged, some are spined, some are smooth on the surface, some are rough, some fluidify the gelatine, some do not, some form curious bizarre figures, some are delicately lined. You may now take a needle, which you have just before made clean by heating it red-hot in a flame, and, as soon as it is cool, plunge it into the colony. A few thousand germs more or less will stick to the needle point, and you now carefully pull out the cotton plug from a fresh tube of the solid gelatine, and scratch the needle point over its surface, or plunge it into its depth, withdraw the needle, and plug the tube up again, and set it away in a warm place. In the same way you may plant your germs on milk or potatoes, or on other germ foods. You have planted in this tube only one species of bacteria from the one punctured colony. These presently will grow, and then you have at last a pure culture of one of the invisible microbes which you assumed to be present though unseen in the water in which we went a-fishing.

Recovered from the fatigues of our fishing experiences, suppose we set out on a hunt for aerial germs.

One of the most curious phases of hunting in which the writer ever participated was in the far West, while on the plains the antelope were still abundant and comparatively tame. When we came in sight of a herd of antelope, if the sportsman, or even a whole group of them, carefully dismounted, so as not to frighten the game into a panic, and one or two of the hunters slowly waved colored handkerchiefs to and fro, often the whole herd would slowly approach the men, and could be easily captured at short range. The game came itself to the trap.

Well, with as little exertion we hunt our invisible aerial germs.

We melt some nutrient jelly, and pour it out on to the bottom of a shallow glass dish, and let it cool and solidify. All we have now to do is to set the dish uncovered almost anywhere we choose, in an inhabited room or out-of-doors, in any town, and leave it exposed to the air for, say, five minutes. We know that gravity is constantly bringing toward the earth floating dust particles and other minute bodies, and that germs are very apt to be clinging to dust particles everywhere. So what curiosity did for the antelope, gravity does for the germs—lands them in the trap; and at the end of five minutes we quietly cover the dish and set it away. We see nothing on the surface, and a triumphant home-coming from our hunt is therefore out of the question. But in a day or two, just where each invisible atmospheric waif fell on the moist surface of our gelatine, a colony will appear and continue to grow.

Thus we can make analyses of the air, and learn approximately how many living germs are floating and falling in the stuff we breathe.

The long series of observations and experiments which every single species of bacteria thus isolated from the earth or air or water must be subjected to before we learn its life history we need not dwell upon. This hurried outline of the method of isolation must suffice. By the same general methods, though with many details and many modifications, we separate the germs which have caused disease in the living body.

Many of the bacteria do not grow at the ordinary temperature of the air, and so we have in a special room some copper ovens, called thermostats or hatching ovens or incubators, kept at a perfectly uniform temperature, about that of the body, day and night, into which we can put our culture tubes. No human nursling ever received more devoted attention than do these tiny life sparks, as hour by hour their growth goes on. Some of them are veritable microscopic devils, but all alike come in for a share in the delicate ministrations of their foster-parent, the bacteriologist. Some bacteria do not grow in contact with the air, and for these we must have an apparatus to pump it out, or to replace it with some other gas, such as hydrogen.

Now these various methods of cultivating bacteria and other forms of germs on solid transparent culture media were largely devised and elaborated by one of the most patient and painstaking and conscientious workers of the present day, Dr. Robert Koch, of Berlin, early in the present decade. To the skill and cleverness with which he devised and perfected the comparatively simple technique of bacteriology is directly traceable some of the most momentous and valuable discoveries of this or any other age. Very hazy and incomplete were the glimpses which before this time had been caught of this vast world of the infinitely little, because the methods of study were so crude and inaccurate. Now, however, discovery is piling itself on discovery, not only in the field of bacteriology at large, but in the relationships which certain of the germs bear to serious human and animal diseases.

To this relationship we must now briefly turn.

It has been learned within the past few years that several of the most serious diseases known to man are caused by particular species of bacteria. Such diseases are called infectious. Amongst those forms which thus originate are tuberculosis, Asiatic cholera, erysipelas, and some forms of blood-poisoning, tetanus or lockjaw, some forms of pneumonia, typhoid fever, and diphtheria. We know the germs which are concerned in the causation of these diseases, and can grow them in tubes in the laboratory, and work out their life history.

There are other diseases belonging apparently in the same general class, of whose mode of origin we are still largely ignorant. Such are small-pox, measles, scarlatina, yellow-fever, and others. We believe, largely on the ground of analogy, that these too are caused by some forms of germs, each after its kind, but what they are we cannot yet say.

Malaria, it has been pretty well established, is due to a minute organism which belongs not among the plants, but low down in the animal series, in the class known as the protozoa, and it may be that some or all of the last group above-mentioned may be caused by similar organisms, which as yet we cannot cultivate in the laboratory, or even bring within our vision with the microscope. Let us then confine our study to those diseases whose causation has been well established.

We have not space, nor would it be fitting, here to consider these diseases in detail, one by one.

Each of the species of bacteria which cause disease differs from all other forms, and has a distinct and characteristic mode of life. They are, for the most part, confined to the bodies or the vicinage of persons suffering from or subject to the respective diseases. This we say, in scientific parlance, is their "habitat," in distinction from the large proportion of bacteria whose natural habitat is outside the human or animal body, as in the soil or water, or on other plants.

It follows from this that if we could destroy all the materials discharged from the bodies of affected persons, or those temporarily harboring the germs, so that these could not be spread abroad and come in contact with other persons or animals, we could largely limit if not ultimately completely eradicate these infectious diseases. The demonstration of this fact is one of the most important of the achievements of modern bacteriology, because it leads us to the hope that in the not far-distant future we may be able to prevent a great deal of sickness and premature death. This consideration alone far outweighs in importance the sense of uneasiness which is to-day so wide-spread among all classes when the relationship between germs and disease is spoken or thought of.

Consumption, or tuberculosis, is largely spread by the specific bacteria in the sputum thrown off by affected persons, which is allowed to dry and become disseminated in the floating dust. Typhoid fever is communicated by the germs discharged from the bodies of those ill of this disease, which, in one way or another, but largely in polluted water and food, get into the digestive track of well persons. Diphtheria may be communicated in like manner by the germs in the membranes or fluids from the mouth of the stricken ones, and may linger long wholly dry in garments and household furniture and rooms.

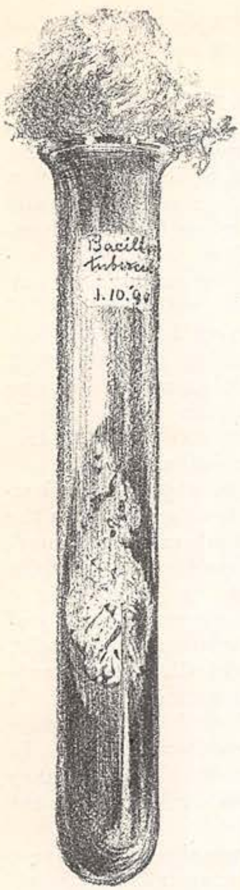
The bacterium causing tetanus, or lock-jaw, is not often conveyed from one person to another, but is exceptional in having its usual lurking-place in the soil of certain regions.

Now how do these particular species of germs cause these special forms of disease? We have already seen that one of the marked life features of bacteria is that when they assimilate nourishment and grow, they set free various forms of chemical substances. When putrefaction occurs in a bit of meat, for example, certain bad-smelling gases, as well as a host of other substances, are set free by the bacteria which are feeding on the meat. These cause its putrefaction. Each species acts in its own peculiar fashion in the acquirement of its food, and sets free its own peculiar chemical substances.

Now the same thing happens when bacteria, in one way or another, get into the bodies of men or animals and grow there. But in the large proportion of cases the bacteria which we take into our bodies in vast numbers with the greatest variety of uncooked foods and with water and milk, produce, if they grow at all, chemical substances which do no manner of harm. It is indeed not at all improbable that some bacteria which are constantly present in the digestive canal form, under ordinary circumstances, materials which aid in the process of digestion.

It has, however, come about in the lapse of ages that a very few, an infinitely small proportion, of all the bacteria which are about us produce chemical substances in the body which in one way or another act as violent poisons. These substances produced by bacteria are called ptomaines, and here at last our plummet seems to be striking bottom. It is the ptomaines, or peculiar vegetable poisons produced by these germs, which usually do the damage. Sometimes these ptomaines are produced in some special part of the body where the bacteria grow, and, gaining access to the body fluids, are carried all over the organism, inducing in the most vulnerable parts those changes which are characteristic of the disease, and which give rise to what we call its symptoms. This seems to be the case in diphtheria and typhoid fever, in which the bacteria are confined, in the former, usually to the mouth and throat and air-passages, and in the latter, to the intestinal canal. But the soluble ptomaines are carried everywhere, working havoc.

On the other hand, in the complex of



A "TUBE CULTURE."
The tubercle bacillus.

disorders known as blood-poisoning and in tuberculosis, the bacteria may be widely distributed in the body, producing wherever they are the poisonous stuff.

Some of the poisons formed in the body by disease-producing bacteria have been isolated from artificial cultures of the germs by delicate chemical manipulation, and have been found in this pure form to be so extraordinarily powerful that even excessively minute portions of them introduced into the body induce the symptoms of the disease. They have even been isolated from the bodies of persons who have succumbed to the diseases, and have shown in animal experiments the same intense powers.

It has been recently learned that outside of the body, in certain forms of food, such as stale milk and cheese and sausages, bacteria may grow and produce a virulent poison. When such food is eaten it may cause immediate serious results, not because of the bacteria which it now contains, but because of the poisons which they elaborated there before the food was consumed.

Now there is another aspect of this subject which we must not overlook, brief as must be our survey of it. It is true that it is the bacteria which are the primary and indispensable factors in causing these diseases; but the condition of the body is very important indeed in determining whether, when the special germs gain access to it, they shall be able to set up the disease at all; or, if they do so, whether it is to be in a severe or mild form. In other words, there is a condition of the body which, in the presence of any given disease-producing germ, is called *predisposition* to its incursions. There is also an opposing condition which we call relative or absolute *immunity* to its development and progress.

It used to be thought that tuberculosis was hereditary. We know now that it is not; the germ causing the disease is not transmitted before birth from mother to child. A predisposition to the acquirement of the disease, and liability to succumb to its ravages when it does occur, may indeed be inherited; but keep from the body this particular germ, and the predisposed individual is as invulnerable as his more fortunate fellows.

The same sort of influence, as yet little understood, is at work in the body in the presence of most of the acute infectious diseases, though in none of them is the hereditary character of predisposition so marked as in tuberculosis.

Now this vulnerability to the incursions of disease-producing germs is not necessarily hereditary nor born with the individual, but may be acquired in many ways. This phase of our subject leads us to a practical lesson in personal attention to health which we may turn to our advantage.

It is pretty safe to say that excesses of any kind, any form of general ill health, may at times render us more vulnerable than we should naturally be to the action of disease germs.

A very curious series of experiments in animals has been made with a view of determining the effect of general bodily condition on the body's power to resist bacterial infection. It has been found, for example, that the ptomaines produced by one species of germ when introduced into the body rendered it liable to the incursions of other germs to which it was before practically immune. It was found that rats were not at all affected by inoculation with a certain species of bacteria. The experimenter, however, put some of these rats in a little apparatus like a tread-mill, in which they were made to run until exhausted, and now he found that they readily succumbed to an inoculation with the same germs. So in certain animals prolonged fasting changes their condition from one of practical immunity to one of extreme susceptibility.

The lesson of these experiments is written so large that surely he who runs may read.

There is an inherent capacity of resistance to deleterious influences of various kinds on the part of the body, which can be strengthened by suitable food and regimen and proper hygienic surroundings. This health inertia alone carries many safely through the struggle with the various forms of bacterial disease. Up to the present time the physician's function in treating bacterial diseases has been largely limited to bracing up the body's cells by drugs or proper food, or in some other way which experience has shown to be more or less efficacious, so that they might carry on their fight under the most favorable conditions.

But since new light has dawned upon the relationship of bacteria to disease the student in this special field has not been idle. While slowly and toilsomely working out the life story of the germs one by one, he has held ever close to his heart this most cherished hope that by-and-by we should know enough about the secret life of these invisible foes of man to enable us to destroy them in the body outright, or in some direct way control their ravages. With this shining possibility ever luring him on to new researches, several very significant facts have been brought to light.

It is well known that there are certain diseases one attack of which more or less effectually protects the victim from subsequent liability to it. Although such diseases in man belong chiefly in that class above alluded to whose relationship to micro-organisms has not yet been definitely made clear, it has yet seemed possible that the same condition might be brought about in well-understood bacterial diseases by artificial inoculation if only we could get some variety of the specific germ of such diminished virulence as not to be in itself dangerous. It has been learned, in fact, that by putting pure cultures of certain disease-producing bacteria under such adverse conditions as to make life a burden to them, but not quite killing them, as, for example, by alternately heating and cooling, a variety of the species could be produced which when inoculated would cause no serious harm, and in a measure confer subsequent immunity, much as vaccination does against small-pox. This preventive inoculation has been largely practised in Europe in several forms of germ disease in animals, with varying success.

It has been thought also that if the ptomaines which the disease-producing bacteria form as they grow could be separated from the germs in suitable form, these ptomaines might bring about immunity by introduction into the body. Much research has been made in this direction both in Europe and in this country, and it really seems from the successful experiments upon animals as if before long some very significant revelations in this direction might be forthcoming which will be of direct benefit to man.

On the other hand, experiments which have thus far been made in the way of attempts to destroy the invading germ by the direct use of chemical substances put into the body which should not harm the body cells themselves have not led to very encouraging results.

It will be seen from these hasty indications of some of the salient features of the infectious or bacterial diseases that we are standing to-day on the border-land of a vast unexplored region in the domain of life. It seems to be a region rich in the promise of benefit to man, when after patient toil we shall have learned more of the relationships of these tiny organisms to one another and to higher forms. The richest harvest garnered hitherto in this domain has been the power to understand the cause of certain dread human scourges, and thus to stay their progress.

In the face of threatened epidemics of Asiatic cholera, we stand to-day fully equipped with a knowledge of its nature, which surely enables us to hold it successfully in check. The surgeon can to-day undertake with just confidence of success such operations for the relief of suffering humanity as would have made the hearts of his elder *confrères* stand fairly still. Many of the so-called accidents of maternity have largely lost their vagueness, and with this their power to harm. The great cloud which for so many years has hung low over the heads of the children of tubercular parents has at length begun to roll away. The terrible epidemic scourges of former times no longer haunt the imagination.

Man is not in these days a serious seeker for the fountains of perpetual youth, nor may we justly long for earthly immortality. But we now see—dimly, but at last—that we may lay larger claim at least to our allotted threescore years and ten if we can but learn to cope with or to hold at bay those unseen enemies which have robbed us already of far too many lives.

Little by little we are learning that prevention is better than cure, and that prevention is possible in a large number of those diseases which have claimed their victims hitherto unchallenged. People have always taken it as a matter of course that a certain number of persons must sicken and die of such diseases as typhoid fever and diphtheria; but we know to-day that these diseases can be largely limited if only proper care be taken in destroying the waste material from the sick. We know now to just what we must attribute the wide-spread acquirement of tuberculosis, and that proper cleanliness in affected persons, and proper cleanliness in streets and houses and all assembling places, would greatly curtail the number of its victims.

Still, again, these delvings in the unseen world have brought up at least one shining moral nugget, which, when beaten into words, means something like this: *we must not lay at the door of Providence or fate those evils which we wilfully or ignorantly bring upon ourselves.*

But, some one will say, amid all these glittering hopes for the future, amid all your congratulations over the large achievements of the past, what is there here and now, at once, to-day, of help for the already stricken? Patience, patience. The wise physician can do much along the lines which experience has drawn to comfort and to save. We do but harm ourselves to strain too eagerly to catch the assurance of the coming day.

It is coming, slowly perhaps, though we do not know how soon; but it is coming, we may assuredly believe, the time when we shall have so far mastered the life history of our invisible enemies in this hidden world of life that we can fight them with their own weapons on their chosen fields. Hundreds of tireless workers the world over are toiling early and late to usher in that day. It is a pity that some of the large-hearted men in this country, in whose hands great fortunes are placed for a little while, do not see to it that suitable endowments of research in this most promising field are furnished here, so that we may more fairly join hands with the workers in other lands whose authorities are more keenly alive than ours to the urgency of the claims of suffering men.

Our national and State legislators and department officers are wide-awake enough to the economic interests which are threatened when cattle feel the touch of bacterial disease; but for man no hand is raised.

There has never been a time in the world's history when well-directed and well-sustained scientific research promised so much of positive and direct benefit to man as it does here in this underworld of life to-day.

As I write, there comes flashing to us across the sea the cheering word that the great master in this field, Robert Koch—the man whose suggestions about modes of working have made possible the great advances in biology of which I write; the man who discovered the cause of the greatest scourge of the human race, tuberculosis; the man whose keen insight and patient toil led him in a host of others to find out the fateful germ of the dread Asiatic cholera—we hear, I say, that this master's deft fingers and well-furnished brain have brought him to the belief that a large measure of help is close at hand for many of the victims of tuberculosis. How far-reaching this discovery may prove to be when we know all its details, we cannot even fairly conjecture yet.

But of this we may be assured, that what toil and skill and learning and self-sacrifice can do will be done the world over to bring as speedily as may be the acquisitions of this science and lay them at the service of the hapless victims of bacterial disease. In the mean time the public is taken so fully into the confidence of the medical profession as to the nature of these problems which are urging to be solved because in large measure the burden of prevention rests upon themselves.

When we gather up the lines of thought and research which we have followed so hastily together, we find that they are all pointing for each of us not to a state of watchful unrest, not to a brooding apprehension, but toward one practical suggestion—the need of a more general and a more intelligent cleanliness.