# The WORLD of INVISIBLE LIFE

By MARY BOWEN STEPHENSON

# WORLD *of* INVISIBLE LIFE

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*The Story of Microscopic Life*

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*Publishers' Note*

This book presents in popular form the present state of science. It has been reviewed by a specialist in this field of knowledge. An excerpt from this review follows:

> *"This book contains a number of essential and significant facts told in a simple, clear, and interesting manner. It discusses many things that young people as well as their elders should know about the small organisms which the human race has discovered in the past fifty years to have such potent influences on life and health and on the momentous changes that take place in the world around us."*

Edwin Oakes Jordan
*Professor of Hygiene and Bacteriology*
*The University of Chicago*

*When Spring unlocks the flowers to paint the laughing soil.*

—Reginald Heber

# The WORLD of INVISIBLE LIFE

*By*

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*Drawings by*

MARY N. MULLIKEN

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## Chapter I

# THE WORLD OF INVISIBLE LIFE

THROUGH a wonderful invention called the *microscope,* we can look into a world that our forefathers, a few hundred years ago, knew nothing about. They did not even know that there was such a world. Yet it is a world full of strange and interesting forms of life.

*What is a microscope?*

The word *microscope* comes from two Greek words meaning "small" and "to see." This instrument is simply a brass tube with several lenses. A lens is usually made of two pieces of fine glass, one thicker in the middle than at the edges, and the other thicker at the edges than in the middle, the two pieces being carefully fastened together. There are one or two larger lenses at one end, which is called the eyepiece, and several smaller lenses at the other end, which is called the objective.

All of these lenses can be changed about, so that whatever is to be examined may be enlarged to exactly the right size to enable us to see it clearly.

*How does a microscope work?*

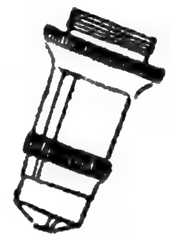
The brass tube is fastened to a stand which holds it upright, and which has a little table with a hole in its center just below the end of the tube. A mirror below throws light through this hole into the brass tube. Whatever is to be examined is put on a glass plate called a slide, which is then fastened to the little table. A moment later, when we put our eye to the larger lens at the top and look down through the tube, we see a clear picture, many times enlarged.

A microscope such as those used by scientists in their laboratories is not so simple as ordinary microscopes, and costs a great deal of money. Such a microscope is often so powerful that it can enlarge things hundreds and even thousands of times their real size.

If we take some cloudy water from a pond into the laboratory and put a drop of it on the glass slide of a microscope, we can then take a peep into the World of Little Things that we can never see with our unaided eyes. Under a microscope that enlarges things 500 times, we shall see a really marvelous picture. Who would have thought of such a thing! That drop of water is alive with tiny, odd-looking creatures moving about in it very swiftly. There are many different shapes among them. Some are fish-shaped, and some are globe-shaped. Others have a fine skeleton of lime or are covered with shells, like tiny snails. Some have countless, fine wavy hairs, like a fringe, around their edges, which they move back and forth, and by doing so are able to travel through the water. Among these little living beings that whirl about in the drop of water are also some curious thread-like objects. These are the plants of this wonderful world of the microscope.

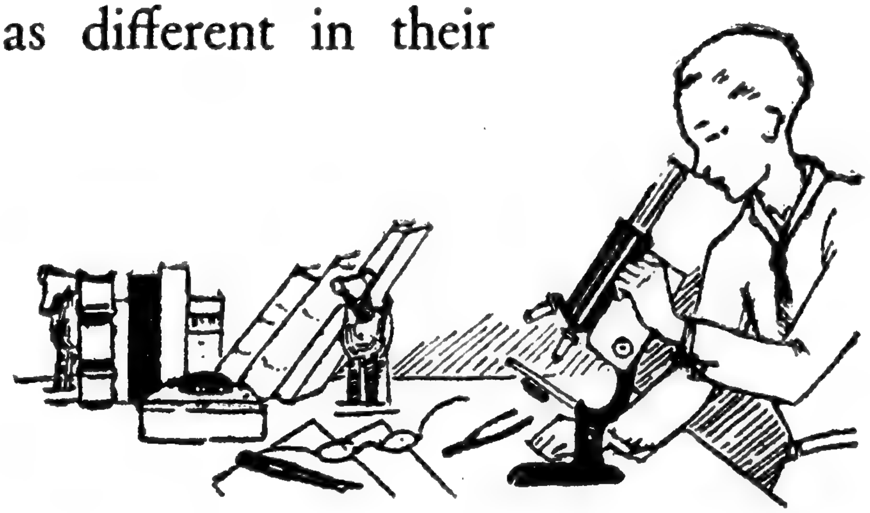
*What can be seen through a microscope?*

*Eye piece*



*Objective*

We see that this one drop of water contains a whole world of its own, with animal and plant inhabitants, which are as different in their



*Many interesting things may be seen through a microscope* forms, shapes, and sizes as are the creatures in the world we see about us. Some of the tiny folk of this other world are beautiful and interesting.

When we enlarge the drop still more, to about 1000 times its actual size, we can see some even smaller living things. They look like little straight sticks, or spirally twisted threads, or tiny round dots.

*Where are living things found?*

Scientists have found that not only is the water full of this invisible life, but that life of this kind is everywhere about us. The air is filled with tiny living things, and so is the soil of the earth. They are on everything we touch and in everything we eat or drink. Most of them are harmless, and many are useful to us. However, there are certain kinds which make us ill, or spoil our food, or in some other way are dangerous to us. They are all known as *microbes,* and each separate kind has its own name as well.

At first, all the microbes in the drop of water under the microscope seem to be merely black, white, or gray lines and dots, with only now and then a bit of green or red. Naturally, they are hard to see clearly. To make them much easier to see, we add a little specially prepared dye of red, blue, purple, or yellow, to the drop of water. Certain parts of the microbe will absorb the dye and take on a brilliant coloring, though such a stain usually kills the little animal. If the drop of water contains several different kinds of microbes, we can dye them different colors, for it has been found that one kind of microbe will absorb only a certain color, while another type will absorb only some other color. For the same reason, we can even dye one part of a single microbe one color and another part a different color. Of course, this is a delicate process. It has taken many men years of work and study to perfect it, and only one who knows a great deal about it and is very skillful can do it.

*How can we see invisible things?*

In order to study any one kind of microbe, it is necessary to separate it from the many others that are around it. Then one may study its various stages of development. The separation is accomplished by growing our own microbes. For instance, we take some of the cloudy water which we looked at under the microscope, and which we found contained many different kinds of microbes. We pour it over some substance that contains the proper kind of food for the microbes.

*How can we grow them for ourselves?*

The most common material is a kind of gelatin, but we could use slices of raw potato, or milk, beef broth, or several other foods just as well. The gelatin is poured into a dish where it jells. After a few days many spots appear on its surface. Then we take a platinum needle set in the end of a glass rod and pass it through a flame to kill all the microbes on it. We touch one of the spots with the point of the needle and then touch another dish of gelatin, the surface of which has been sterilized; that is, made clean.

After a few more days, a spot will appear on the second gelatin containing only the particular kind of microbe which formed the spot we touched on the first dish. If we do this three or four times, being very careful each time to have everything we use absolutely clean and free from any other microbes, we will have a large and pure growth of the microbe we wish to study. We can now take a portion of this growth, stain it, and look at it under the microscope. Thus we are able to study, in all its stages, the kind of microbe we have grown, and so learn all about its life and habits.

*How can microbes be studied?*

## Chapter II

# THE MICROBE

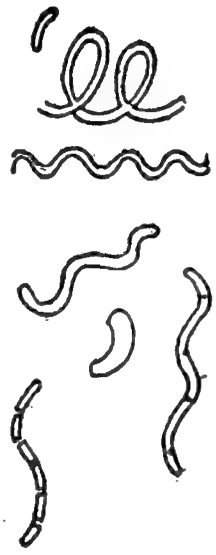
*What is a microbe?*

MICROBES, as we have noticed, are so small that they cannot be seen with the naked eye, but only with a microscope that enlarges things a thousand or more times. A microbe is the smallest living thing that we know. But how small is that? It will help to give us an idea if we say that the point made by the period mark at the end of this sentence would cover about a quarter of a million microbes of average size. They vary a great deal in size, however. There would be about 25,000 of the averaged sized ones to an inch; of the smallest ones, 50,000 to an inch; while of the largest ones, only about 1,000 to an inch.

We know that there are other microbes which are even tinier; in fact, so small that even the strongest microscope, enlarging three or four thousand times, will not show them. They are known only by the work they do. They are called either "ultra-microscopic," because they cannot be seen with a microscope, or "filter passers," because they pass through the finest filters we can make. The germs which cause smallpox, measles, infantile paralysis, or rabies, are all filter-passers, and have never been seen under a microscope.

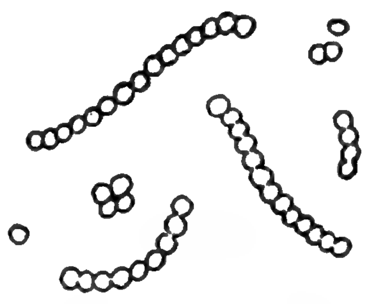
*Are there microbes we cannot see?*

They are the simplest as well as the smallest living things. Those that are large enough to be seen under the microscope have been found to consist of only one cell, instead of many cells, as do larger plants and animals. Though they have no green coloring, most of them belong to the plant kingdom. The different kinds of microbes have different shapes, and the shape of a single kind of microbe often changes as it grows. The smaller microbes may be roughly divided into three simple kinds, depending on their shape: the round kind, called the *coccus;* the rod-shaped kind, called the *bacillus;* the spiral-shaped kind, called the *spirillum.*

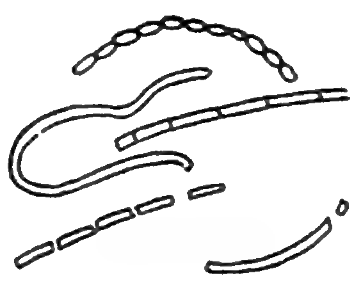


*Spirillum*

*Types of microbes*



*Coccus*



*Baccilus*

*How do microbes move about?*

Some microbes cannot move about at all, while others move only when grown in certain substances. Their ability to move around depends on their having a tiny hair-like fringe, which the microbe waves back and forth and so travels through the liquid. These hairs are called *flagella.* Some microbes have many more flagella than others. The typhoid bacillus has ten or twelve, while the colon bacillus, its near relative, has only from two to six. Many kinds of microbes have these hairy fringes, and so can move about wherever they please. Even their rate of speed has been roughly measured. The typhoid bacillus can travel about 2,000 times its own length in an hour, and the cholera spirillum, for a short distance, can go as fast as seven and a half inches per hour.

*How do they grow?*

Microbes increase rapidly. A young cell grows to full size in less than an hour. That is much quicker than any other form of life reaches full size. Most microbes multiply themselves by simply splitting into two or more pieces, which sometimes remain connected in chains, but more often separate entirely and continue to live and divide just as the original microbe did. This process goes on, once or twice an hour, so long as the microbe is attached to a substance from which it can obtain food. It has been estimated that if the growth of microbes went on unchecked, and the division of each cell took place as often as once an hour, the descendants of each cell would in two days number more than 281 billion.

*Why don't they overrun the world?*

Fortunately, this amazing increase is prevented by many natural means, which keep the microbes from overrunning the earth and crowding everything else out of existence. In absorbing its food, the microbe forms acids and other injurious products, which remain around it and often prevent the birth of more microbes. There may not be enough food for the increased numbers, or the temperature may become too hot or too cold for them to live; or another kind of microbe may drive them out, thus preventing them from increasing so rapidly.

A few kinds of microbes, in addition to forming more microbes by splitting themselves, under certain conditions can reproduce by the formation of eggs, called *spores*. Such an egg, or spore, is able to withstand much harder conditions than an ordinary microbe can; it will sometimes remain alive, though inactive, for years, even without food or moisture. So when one of the microbes which has this spore-forming ability finds itself in a dry place or in one without food, instead of dividing, it forms a spore, which continues to live where the microbe itself could not. Then, when conditions are more favorable, the spore becomes a living microbe.

*What do microbes live on?*

Almost all microbes live on other plants and animals. Some are able to obtain the food with which to keep themselves alive from dead plant or animal matter, while others feed only on living bodies of plants and animals and quite naturally are injurious to the life of the individual upon which they feed. In mankind they produce almost all the diseases from which we suffer, for most disease-germs are of this class.

It is these microbes which live on living bodies that we must try to guard against. We cannot escape all of them, for microbes are everywhere—in our food, in the air, and on the things we touch during the day. Luckily, most of these are harmless. However, there are some things that we can do to prevent these harmful microbes from causing sickness. We can keep our bodies clean, and care for any cuts in the skin. Few microbes are able to enter the body through the skin if it is well cared for. Brushing your teeth is not just a good habit. It is necessary in order to keep these microbes from growing on the teeth and thus causing decay. Once they have been allowed to grow there, they sometimes spread over the entire body, causing more serious sickness when you are older.

*Where do they live?*

Fortunately, most of the common soil, water, and air microbes obtain their food from lifeless material and are unable to grow when they find themselves in a living animal body. They are, therefore, harmless. There are some kinds of microbes, however, that can live on both living tissues and dead matter. They can produce diseases when they live in the human body. They can also live on the bodies of dead animals and plants.

In addition, there are certain kinds of soil microbes that can exist without depending on any other plant or animal material, alive or dead. They have the ability to make their food from substances in the soil and air, just as plants do. So they need have nothing to do with other animals or plants.

*What does temperature do to them?*

Every microbe has a temperature at which it lives best, and each has a low point below which it is too cold for its life to continue, as well as a high point above which it is too hot for it to live. These points differ greatly for every type, and the low point for one kind of microbe may be higher than the high point for another. One kind of soil microbe can not grow, under certain conditions, below 116 degrees of heat, while the microbe of tuberculosis cannot live for any length of time above the same temperature. Some microbes are able to multiply at, or very near, the freezing point, while others are known to multiply at a heat of 138 degrees. One microbe is known that lives continuously, and multiplies, in the water of hot springs at a temperature of 159 degrees.

Microbes which live in animals or men have a much smaller range of temperature than those which live in the outside world. The favorite temperature for microbes that are harmful to man is near the average temperature of the human body, which is about 98 degrees. Most microbes are killed in temperatures of 131 to 136 degrees, if kept up for ten minutes in moist surroundings.

Microbes can stand low temperatures better than high ones. The common microbes of water and soil, and also those of typhoid fever and diphtheria, have been left for several days at a temperature of 310 degrees below zero without destroying their life or their ability to multiply again when the temperature was raised. However, if these microbes are in water which is frozen, they nearly always die in a few weeks, even though the temperature is not far below freezing.

*What can destroy them?*

The majority of the ordinary microbes are quickly killed by dry air, though there are great differences among the various forms. Exposure to dryness for a few hours, or at most, a few days, destroys most of the harmful microbes, so that the catching of disease-germs through the air, except when the microbes are enclosed in drops of moisture, is rather rare. The tuberculosis germ is one of those which can resist dryness the longest, and the cholera germ is one of those which die most quickly in a dry place. Some of the more complex forms of invisible life, like certain water-worms, known as *rotifers,* can live in a dry place for months or even years, for they are protected by a gelatin covering, which makes it possible for them to exist under dry conditions. The microbe does not have this protective covering, thus its removal from moisture speedily destroys its life.

We all know that most living things need oxygen in order to live. This is also true of most microbes, and for a long time it was believed to be true of all of them. But it has been discovered that a few kinds can grow perfectly well without air, that is, without free oxygen. In fact, many of this kind are so constructed that they cannot live in air.

*Do they need oxygen to live?*

The microbes that must have free oxygen are known as aerobes. They are by far the most numerous group. Most of the common air and water microbes and the majority of the disease germs, such as diphtheria and cholera, belong to this group. We know little about how the second group, which are called anaerobes and are able to live without oxygen, but the fact that they exist has been proved by many scientists who have studied them. Many of the soil microbes belong to this group.

Chapter III

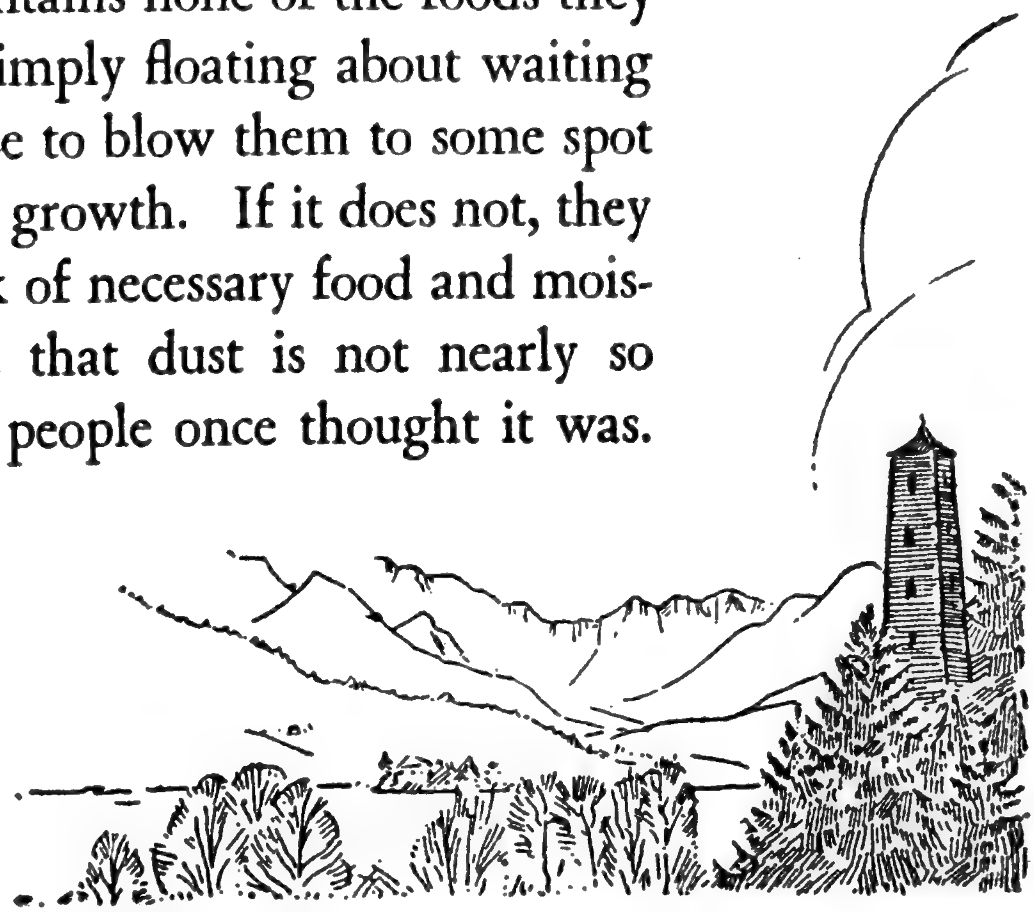
## THE MICROBES IN AIR AND WATER

*Are there microbes everywhere?*

MICROBES are so small that they float in the air and are blown about by the winds for a long time. It is almost impossible, at least in places where people and animals live, to find air that does not contain them. There are fewer microbes in the air of the country than of the city; there are fewer in mountain air than in the air of the lowlands; and the air of the mid-ocean, where no human beings or animals live, is almost free from them. We find that the more human beings there are, the more microbes there are in the air; a room filled with people has many more in the air than an unoccupied room.

Of course, wherever there is dust in the air, there are microbes with it; the more dust there is, the more microbes there are. This would be alarming, were it not for the fact that most of these microbes are of the harmless kind. Yeasts and molds of all kinds are numerous. The hay bacillus, another harmless type, is almost always present, along with many similar forms. As a rule, the microbes which cause disease are rare in dry dust. The germ of tuberculosis, for instance, may float in the air of a room in which a person sick with the disease is living, but it lives only a comparatively short time and is not found in ordinary air. The air of the school-room may contain a few germs from children suffering from colds or other diseases, but if it has plenty of sunshine and fresh air, they rarely live long. The air is not a suitable place for microbes to live in and multiply, for it contains none of the foods they need. They are simply floating about waiting for a chance breeze to blow them to some spot favorable for their growth. If it does not, they soon die from lack of necessary food and moisture. So you see that dust is not nearly so harmful as many people once thought it was.

*Are they harmful to us?*



*Mountain air is nearly free of microbes*

*Does sunlight affect them?*

It has been found by various tests that direct sunlight kills many microbes almost at once, and that even ordinary daylight hinders their growth a great deal. They grow best in the dark, and so dust or dirt exposed to sunlight soon loses most of its living microbes. Scientists have found out that it is not the heat of the sun which kills them, but certain rays in the sunlight. These are called the *ultra-violet rays,* because they are beyond *(ultra)* the violet rays in the band of colors that we call the *spectrum.* We cannot see these rays, but they are powerful and health-giving. These ultra-violet rays are often used to purify water.

The action of sunlight on microbes can be shown by covering part of a plate upon which microbes have been grown in the laboratory, and allowing the sun's rays to beat down upon the rest of the plate. Large families of microbes will grow in the covered part of the plate, but there will be no new growth in the part that is open to the sunlight. It has been found that the electric light will produce the same result.

The fact that light is so fatal to the growth of microbes is another reason why air and dust are so much less harmful than we should think from knowing how many microbes there often are floating about in it. It also explains why dark places breed disease, and why people, in order to keep healthy, need plenty of sunshine.

*Can they live in water?*

Almost all the bodies of water on the earth are filled with microbes. Unlike the open air, which, as we have seen, is not friendly to the growth of microbes, water makes a good home for them. It nearly always offers the right temperature and abundant food for many kinds of microbes. They are washed into it from the air and the soil and from the living and dead bodies of plants and animals. So almost any microbe, harmless or harmful, can sometimes be found in it. But, although great numbers of microbes flourish in the water, a far larger number make their way into it from time to time and live only for a certain time.

In spring-water, which comes fresh from the ground, the number of microbes is fewest.

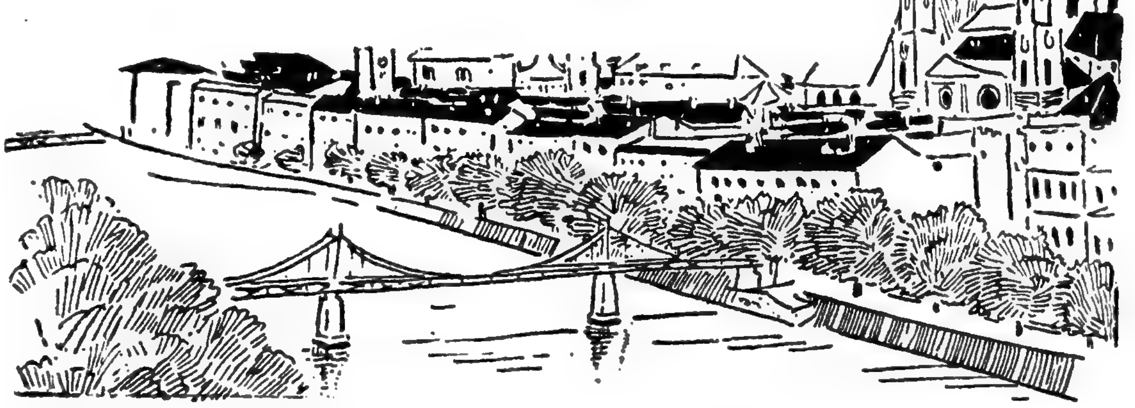
*What water is purest?*

There are few also in deep well-water, coming from a depth of a hundred feet or more, for soil microbes are not found far below the surface of the earth. All waters near the surface of the earth, or waters open to the air contain them. But they are fewer in standing waters, such as lakes and ponds, than in flowing streams. We usually think that river water is purer than that of ponds or lakes, but this is not true. The reason is that rivers and brooks gather the microbes from the earth which is washed into them by rains, and carry them along. The rivers are the great drain-pipes for the country and the farther they go the more microbes they contain. But when water stands still, as in lakes and ponds, the microbes, being a little heavier than water, settle to the bottom in a few days; so after a time the water becomes far purer than any river. Rivers into which sewage or other decaying matter is emptied, of course, contain many more microbes than any other, and in such water we find the most dangerous germs; those cast off by sick people.

The two most common diseases known to be transmitted by water are typhoid fever and cholera. Both find their way into water via sewage from the homes of people sick with one or the other of these diseases. But neither germ finds the right food there, and so lives only for a short time. Typhoid germs will live for four or five days in natural bodies of water; they do not ordinarily multiply, but become fewer in numbers. Sewage, therefore, is most dangerous immediately after it enters the water, be it river or lake or drainage canal. But the germs can live for some time in the soil, and sometimes are washed into rivers and wells after they have been in the soil for several weeks. They have been known to travel quite a distance in the water, at least eighty or ninety miles.

*Do microbes cause disease?*

The cholera germ is less hardy than the typhoid germ and lives a shorter time in the water, for it is killed by other microbes harmless to human beings. By boiling water for ten minutes, we can completely destroy both



*A river flowing through a city is usually filled with germs* typhoid and cholera germs, as well as any other harmful microbes which may be present. That is why water should be boiled before drinking when we are not sure that it is free from such microbes.

*Are all water microbes harmful?*

The ordinary microbes in water, which are not harmful, are of many different kinds. They may make water cloudy and bad-smelling, but otherwise they do no harm. Many of them have complex structures, as compared to the simpler microbes. They even have mouth openings and a sort of stomach. Some of these are called *Infusoria,* others are *amoebas,* and another kind are called *rotifers.* Some are green when seen through the microscope. Though these are larger than many of the microbes, they are all too small to be seen without one.

Besides, all bodies of water swarm with the countless kinds of tiny microbes that can live on dead plant and animal matter, but which, as far as we know, cannot thrive on living animals, and so are not dangerous to man.

Most of the microbes in water are killed by freezing it, and so ice contains only a few of the number that were in the water before it was frozen. Most of the harmless microbes die within a week. At the end of six months most ice is almost entirely free from any kind of microbes. And so ice is much purer than the water from which it is made.

*Is frozen water safe?*

We are not sure, however, whether or not typhoid fever germs are always killed by freezing even for a long period. Sometimes, they seem to have been only stunted in their growth, and when the ice is melted, they become active again. We know of one instance where ice was cut from a river near a place where sewage was emptied into it, and when the ice was used, seven months later, it caused many cases of typhoid fever. Samples of the melted ice showed living typhoid germs. But such cases are so rare that we can safely say that nearly always ice is much purer and less dangerous to humans than the water from which it is made.

What we have learned by these studies through the microscope has been helpful in the saving of countless human lives. We have found out that dirty streets, swamps, and refuse heaps caused sickness and the spreading of disease. And at the same time that clean cities are healthful cities. And now we can have our great present-day cities, with wide, clean streets and pleasant living districts. Diseases, such as the Black Plague of the Middle Ages, can no longer cause the death of thousands of people in one city. Before we found out some of the causes of these diseases, the care of a city's health was left largely to chance. As late as 1832 pigs were the only way of cleaning the streets in New York. The old town pump found in so many towns was another way in which sickness was spread rapidly. But today, every city cares about the people's health. A group of men called the Sanitary Board see that the streets are cleaned, that the garbage is taken away, and that the drinking water is fresh and pure. You are taught the value of hygiene in school. And there is "clean up" week to remind people of the value of cleanliness.

*Has the discovery of microbes aided health?*

## Chapter IV

# THE USEFUL MICROBES

ONLY a certain number of the countless microbes around us are harmful to human beings and animals. Most of them are harmless, and it has been found that some of the harmless microbes do useful work. Sometimes they help Nature in ways that are very useful in the lives of human beings. Even some of the things they do that seem troublesome to us at times, are in other ways valuable to us. It is the action of a certain group of microbes that sours milk, without which we could not have butter or cheese. The rotting away resulting from their action in dead plant and animal matter is unpleasant but necessary, for it puts the dead matter into a condition in which it can be used as food by various plants. And if it were not for this rotting away, the world

*What microbes are useful?*

would soon be so filled with dead plants and animals that living things could not exist.

*What is yeast?*

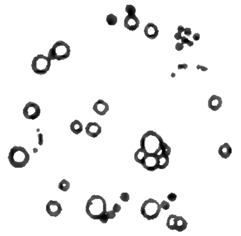
Besides the microbes which act on milk to help us make butter and cheese, there is the very useful group of microbes called *yeasts,* that are used in bread-making and for other purposes. Another group of microbes we can put to work on the job of making vinegar. Other kinds of microbes work for us in the tanning of leather, in the "curing" of tobacco, and in the preparation of flax for making linens, and of hemp for making ropes and cords.

Probably the most useful of all, however, are certain microbes which enrich the soil and make it fertile. Every plant and animal depends upon the fertility of the soil for its life. These microbes live in the soil in great numbers. Then, too, there are microbes in the earth which actually help to build up iron-ore deposits. There are some that perform still other useful duties helpful to both man and Nature.

When we look at milk under a microscope we see a surprising thing. We find that it is made up of many little balls, or drops, of fat, floating in the water which is the liquid part of the milk. They give the milk its familiar white color. These little drops of fat are made up of several substances that are of great value as food for the human body.

*What is in milk?*

Besides the drops of fat, we always find many different kinds of microbes in milk. There are some in the freshest milk, and the older the milk becomes, the more plentiful are the microbes, for milk is one of the best things for their growth. Some of the microbes were in the cow that gave the milk, but by far the greatest number got into it from the skin of the cow, from the hands of the person that milked her, from the buckets which held the milk, and from the dust in the dairy barn. Because milk is such a suitable material for their growth, the microbes multiply in it rapidly, especially if it is kept at ordinary heat. If it is kept cold, however, the number of microbes soon becomes less; so you can see how important it is to chill the milk as soon



*Drops of fat*

*Under the microscope we see that milk is made up of many little balls, or drops of fat* as possible after it is taken from the cow and to keep it as cold as possible until it is used.

*What dangerous microbes can get into milk?*

Most of the microbes in milk only make it taste unpleasant, but sometimes harmful microbes get into fresh milk and bring disease to the people who drink it. These dangerous microbes can get into the milk from the cow herself, or, more often, they may come from certain persons handling the milk. The microbes of typhoid fever, diphtheria, scarlet fever, and sore throat, sometimes get into milk from people suffering from mild attacks or just getting over these diseases. Typhoid fever germs can sometimes get into milk from water containing them which has been used for rinsing out the milk-buckets, or they can be brought to it by flies which have picked up germs from the ground. Tuberculosis and foot-and-mouth disease can come from a sick cow to human beings by germs in the sick cow's milk.

Milk is so likely to contain harmful microbes, and is such a fine place for their growth, that in the past it often caused epidemics of various diseases. Some way had to be found to kill any germs in it before it was used for drinking. It was especially necessary to do this in cities, where the milk had to be brought a long distance from dairies whose sanitary conditions could not be known to those drinking the milk.

*How can they be killed?*

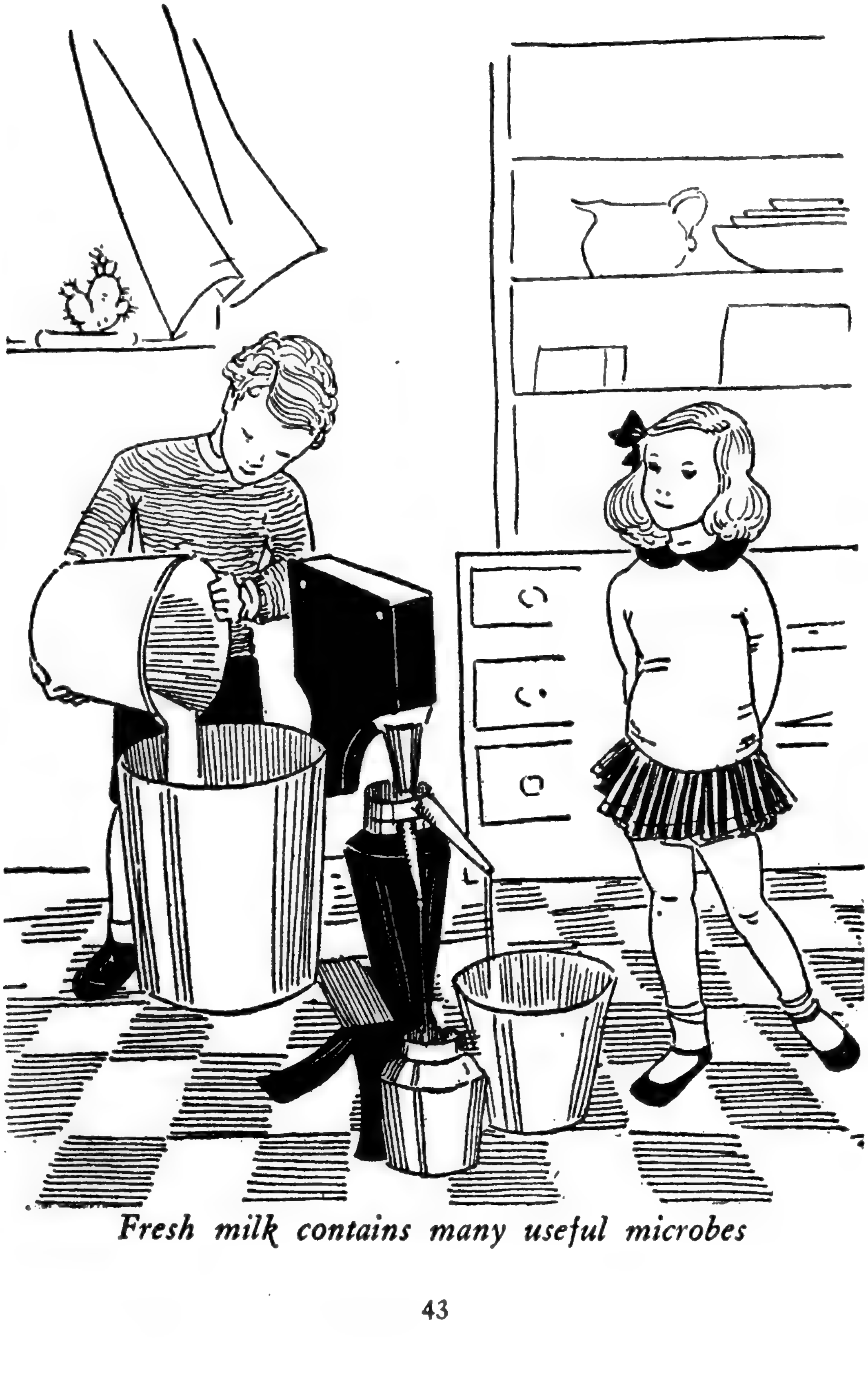
At first, boiling the milk was tried, for boiling kills all the microbes. But boiling also causes certain changes in the milk that make it less easy to digest, besides lessening its food value. It also changes the taste.

For these reasons, another way of treating the milk is now followed, which kills all the harmful microbes. This method is called *pasteurization*. It is named after Louis Pasteur, a famous French scientist who discovered a great many facts about microbes. It consists of heating the milk hot enough to kill the harmful microbes, but not hot enough to cause any marked changes in the milk itself. The milk is heated to 142 to 145 degrees for thirty minutes. Then the milk is cooled rapidly.

*What does pasteurizing do to milk?*

This method is used, by the companies that sell milk, in almost every city in the United States. It has brought about a great lessening in the amount of sickness caused by impure milk. While it does not cause any great changes in the milk, it does stop to some extent the formation of cream, and it weakens one of the healthful things called vitamins in it. But it makes the milk so much safer that we overlook these small drawbacks. There is no doubt but that it has saved countless lives, especially those of babies, who live almost entirely on milk.

When milk is allowed to stand in a warm place, it always becomes sour. For a long time, nobody knew just why this happened. Now we know that it is the work of a group of microbes that are always present in milk and which multiply rapidly except when the milk is kept cold. They are known as the *lactic-acid* microbes. As they increase in numbers, they act on the milk-sugar, which is one of the substances making up the drops of fat in the



*Fresh milk contains many useful microbes*

milk, and turn it into lactic acid. The lactic acid curdles the milk, and so makes it sour. Milk pasteurized at the usual heat sours in the ordinary way when allowed to stand for some time, though if a heat of about 180 degrees is used, even the lactic acid microbes are killed. The milk then spoils through the action of certain other microbes which have survived. Milk that has soured through the action of the lactic-acid microbes is not unhealthy to drink, however. If it were not for the unpleasant taste, it would be just as healthy as fresh milk.

*How does milk change?*

Sometimes other changes take place in milk, rather than the usual souring. The milk becomes blue, or red, or yellow in color, or bitter in taste, or slimy to the touch. Such changes are sometimes called diseases of milk. They also are caused by microbes that find their way into it. Nearly all of these unpleasant changes can be prevented, however, by thoroughly purifying the containers used for the milk, and by observing sanitation in the barns where the cows are kept.

*How do microbes help to make butter?*

The part that microbes play in the making of butter is very important. On them depends the proper ripening of the cream, which is necessary for the making of a pleasant flavor. Butter made from sweet cream has the right taste, but cream that has been soured too long or by the wrong kind of microbe will have a bitter, or fishy, or soapy taste. Some of the lactic-acid microbes, which sour milk or cream, will give the butter a good taste, while others, closely related, will give it a bad taste. There are so many different lactic-acid microbes that the flavor of the butter varies in different dairies and in different countries.

Because of these differences, scientists have spent much time in trying to find out just which of the lactic-acid microbes makes the best taste, and then growing them in the laboratory. They have selected the several kinds that will make good butter when they are put in cream that has been pasteurized to kill any other microbes that might cause trouble. The growing of the pure microbe that is put in the cream is called an artificial starter. To use such an artificial starter successfully, the place where the butter is made, and the containers used, must be kept extremely clean, so that no other kind of microbe, besides the one especially put in the cream, will produce the desired action.

*How do they help to make cheese?*

Microbes play an even larger part in the making of cheese than in the making of butter. When cheese is made, the milk is allowed to sour and then a microbe growth, known as *rennet,* is added, which separates the curds from the liquid. The curd is then ripened by the action of another set of microbes, which grow in it in enormous numbers. The kind of cheese that results, and its flavor, depends on what sort of microbes are used. Most of these microbes belong to a class known as *molds,* and several different kinds of molds are often used in the making of a single kind of cheese. The green spots found in Roquefort cheese are one kind, and give it its sharp flavor. Two kinds of molds are used in making Camembert cheese. One forms the felt-like surface on the outside of the cheese, and the other gives the soft inside its peculiar taste. The holes in Swiss cheese are formed by carbon dioxide gas produced by certain kinds of microbes in the cheese.

Cheese-making is, as you can see, a very complicated process. It seems to depend on many different kinds of microbes acting upon the curds of the milk. It is difficult, for this reason, to be sure that the cheese will turn out in the way desired, for often a wrong kind of microbe gets into it and ruins the taste. The only way this can be avoided is by taking great care that everything used in the dairy and factory is very clean.

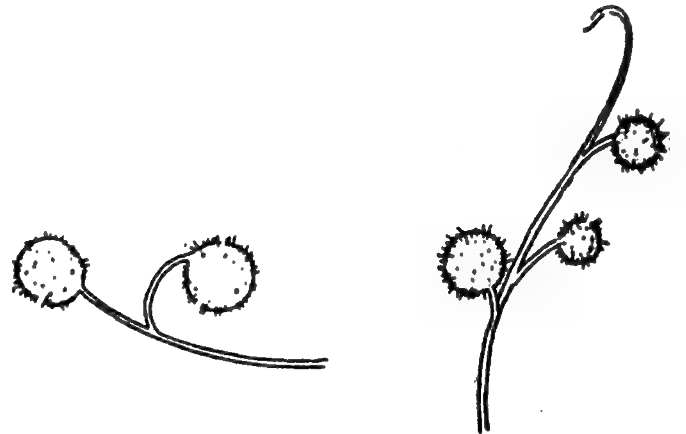
*What is mold?*

Everybody has seen the white felt-like fuzzy growth which sometimes appears on bread that has become damp and stale. Usually, it turns greenish-colored after it has grown for a while. This is one of the most common molds. However, it is only one of many kinds of molds. All of them are plants, and so small that a single plant cannot be seen with the naked eye.

*What are molds like?*

Most molds, when they first begin to grow, are soft, fluffy, white masses, but later they may become blue, green, brown, black, or red. If we look at a mold under the microscope, we see that it is a dense mass of fine white threads. The different kinds vary in the fineness of the thread, the speed with which they grow, and in the color they later take on. These threads, by their growth, work into the depths of the matter upon which they are growing. If they are on the surface of bread, the fine fibers push their way into the loaf. When growing on any soft food, the mold threads, which are seen on the surface, really extend into the substance for some distance, although they are so small and transparent that we cannot see them.

Molds grow on almost all food-stuffs; they can also live, though less easily, on woolen or cotton cloth, or even on leather. Wheat-flour, bread, and cake, are sure to grow mold if left in a warm, damp place. Cheese is one of the very best foods for mold. That is why cheese so easily gets moldy. When molds appear on



*Mold is a small plant which is sometimes useful and sometimes harmful to man* leather or cotton or woolen materials, they are generally called mildew. At first sight there does not seem to be much resemblance between mildew and mold, but the microscope shows that the mildew is nothing more than a certain kind of mold that has not grown very vigorously, because the wool or cotton or leather is not a good food for it. Other kinds of molds grow upon and bring about decay in fruits of all kinds. In fact, under the right conditions molds will grow on almost every food used by man or animals, and on many other things besides.

*What is mildew?*

They will not grow, however, except under certain conditions. The greatest necessity of their life is moisture. They must have an abundance of moisture for a healthy growth, and in dry material they will not grow at all. This moisture may be in the material on which they are growing, or it may be in the air. It is well known that molds appear more quickly and in larger numbers in rainy and damp weather than in dry weather. They will grow, then, in materials that at other times are too dry for their life. They also grow best in places where the air is very quiet. Any wind keeps them from flourishing, probably because an air current drys up the moisture too quickly from the surface of the material on which they are growing. While they grow in both light and darkness, they grow better in the dark than in the light. The action of direct sunlight hurts them, and usually they will not grow on a surface exposed directly to the sun. They also grow best in warm places. A temperature near freezing prevents their growth.

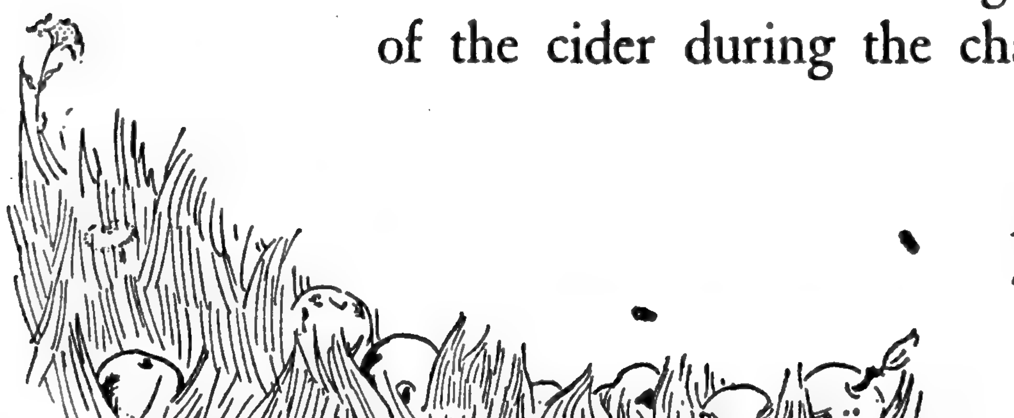
*Where do molds grow?*

Because they grow all through the food on which they live, and absorb part of it for their own food, they cause changes in its appearance, taste, and odor, which usually ruin it. However, in cheese it is the changes that molds produce, and the taste and odor they create that are desired. So the action of mold does not always make food unwholesome, though in other foods than cheese, we usually do not like the new taste and odor; so do not eat them.

*How do they multiply?*

When the mold changes color from the first white growth, to blue-green, brown, black, or red, it is forming the seeds or spores by which it multiplies itself. The tiny seeds or spores grow on the surface of the mold; they are so small and light that they are blown into the air by the lightest air current. As a result, they are nearly always floating in the air, and may drop upon any substance that contains food material for them. There they will grow into molds again, if the proper conditions of dampness and warmth exist.

The sour taste of vinegar is due to large quantities of a substance called *acetic acid*. This acetic acid is produced from alcohol by the activity of a special group of microbes. Vinegar usually comes from cider, which is apple juice that has been fermented, and so contains a small amount of alcohol. The change is brought about by the growth of microbes forming a slimy brownish mass, known as "mother of vinegar," on the surface of the cider during the change. When this



*Apple juice with the help of certain microbes will form vinegar* "mother of vinegar" is looked at under the microscope, it seems to be millions of thread-like microbes crowded together into a slimy mass. These microbes multiply rapidly while the acetic acid is being formed from the alcohol, and it is their growth which causes the change in the cider to take place.

*Why is vinegar sour?*

When vinegar is being made, the freshly pressed apple-juice is usually left to stand in a cool place for five or six months, to allow the alcohol to form, resulting in sour cider. This cider, when allowed to stand in a fairly warm place, will change into vinegar in about fifteen or eighteen months more. Often this change is hastened a little by adding some vinegar containing the "mother of vinegar" to the fresh cider. The cider must be left open to the air, for the acetic-acid microbes cannot live and multiply, and so change the alcohol into vinegar, without a plentiful supply of oxygen, the life-giving gas which we get out of the air.

All of you have seen cakes of yeast. Yeast does not remind you of microbes, and so you may wonder why we talk about yeast as one of the microbes. But yeast is just as much a tiny living thing as any of the other microbes. What we see in a cake of yeast is a group of millions of tiny yeast plants massed together. A single yeast plant is much too small to see with the unaided eye. It is somewhat larger than many other microbes, but it is not much more than 1/2800 of an inch across, and so can only be seen through a microscope. It is an egg-shaped body, quite colorless, and nearly transparent under the microscope, though whitish when seen in a large group.

*Is yeast alive?*

The yeast plants in a yeast cake are in a resting state; that is, they are alive but not growing. They grow and multiply, in a way called *budding,* when placed in water containing the proper kind of food. On the sides of the egg-shaped plant small buds appear as little swellings. They grow until they are as large as the original plant, and after a time they drop apart. Then all the new cells, or plants, grow just as the original one did and split up again into new plants. When a yeast cell is placed where there is not enough food or moisture, it does not grow by the usual method of budding; it breaks up into several parts, usually four, called *spores,* which are able to stand drying, heating, or other hardships for a long time. There are many different kinds of yeast, and not all of them can form spores, though a large number of them do.

*How does yeast grow?*

Dried yeast cells are found everywhere in nature, being blown about in the air. Yeast lives and grows in the soil, in decaying fruit, and in many other places. Nearly all kinds of yeast require sugar in some form for food, and do not grow rapidly where they cannot get it. They cannot live on pure sugar, since they need certain other things for food also; but food-stuffs containing much sugar, such as molasses and grape juice, give yeast all it needs for its healthy growth.

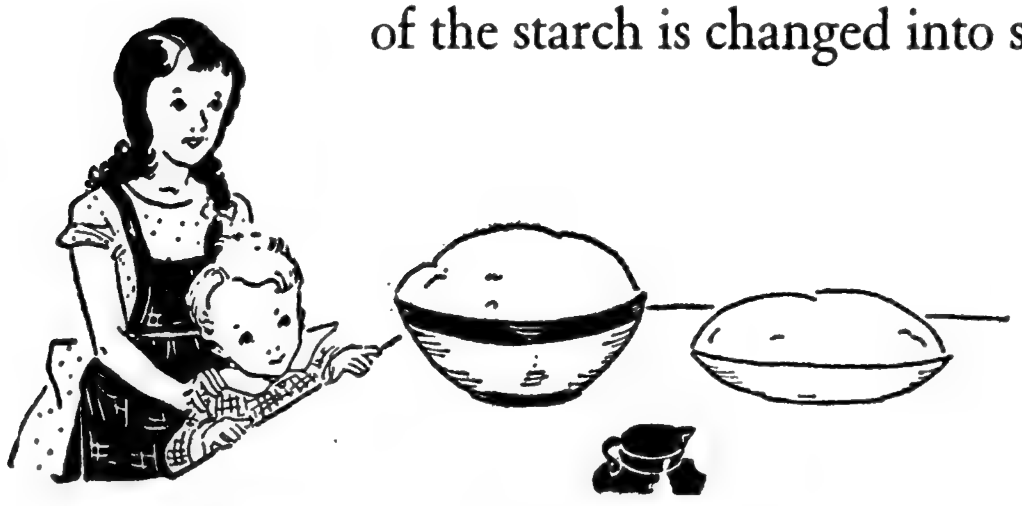
One of the big jobs yeast does is called *fermentation.* It is this that makes alcohol from sugar. Fermentation breaks up the sugar

*What does yeast do?*

contained in a liquid into two other substances. One of these is alcohol, which remains a liquid. The other is a gas called *carbon dioxide,* which usually escapes from the liquid in the form of bubbles. Fermentation is a common thing in nature, and is always caused by the growth of yeast plants. It does not happen unless the yeast plants are not only present, but also are growing and multiplying. There are such large numbers of yeast cells everywhere in the air that any mixture containing sugar, if it is left standing uncovered in a warm place, will soon begin to ferment.

*Yeast microbes*

The raising of bread is another work done by the yeast plants. It is caused by the second product of fermentation—carbon dioxide gas. It is really simple and easy to understand. Bread dough always contains a small amount of sugar which comes from the flour. Besides, there is a good deal of starch in the flour, and a small amount of a substance known as *diastase.* By the action of this diastase, part of the starch is changed into sugar, and so there



*Without the yeast microbes, bread would not rise* is always in dough, after it is mixed, enough sugar for the yeast to grow in and cause fermentation. It begins to feed on the dough and thus ferments the sugar, making carbon dioxide and alcohol. The alcohol mixes with the water in the dough, and the carbon dioxide forms into small bubbles. The dough is so sticky and heavy that the gas cannot rise out of it into the air, as it does from liquids. It collects as small bubbles in the midst of the dough, and causes the dough to swell out. As a result, the bread "rises." Then, after the proper kneading, the dough is put in the oven to bake. The heat of baking drives off the small amount of alcohol that has been formed and makes the bubbles of gas expand so as to enlarge the holes. It also hardens the dough into the firmness of bread. The holes formed by the gas are changed into the countless tiny openings in the bread, making it light and easy to digest. Yeast also gives the bread its flavor.

*How does bread rise?*

The yeasts used in raising bread have been carefully chosen from the many kinds of yeasts that there are, because they have been found to be especially suited to this work. Yeasts differ in their power of producing fermentation, some result in stronger fermentation than others. Since the value of yeast in bread-raising is dependent entirely on its ability to do the job of fermenting, only the most vigorous yeasts are used for that purpose. They are grown especially for the use of bakers, and are carefully separated from any other kinds of microbe or even any other kinds of yeasts. Impure or wild yeast will give bread a bad flavor, cause it to sour, or will not raise it at all. Any other kind of microbe that may be mixed with yeast may interfere with its successful working. So only the purest kind of cultivated yeast is used nowadays for raising bread.

*Are there bad yeasts?*

Yeasts have many other uses, but in all of them their action is the same—that of fermenting sugars. Sometimes it is the alcohol that is wanted and sometimes the carbon dioxide gas, but both are always produced when yeast is used.

Enriching the soil, that is, making it fertile, is one of the most important uses of microbes. All plants, of course, depend on the fertility of the soil, for it is from the soil that they get most of their food. And as animal life feeds upon plants, it is therefore necessary always to keep the soil rich in food materials. A group of microbes which live in the soil in enormous numbers play a large part in keeping it supplied with one of the materials most needful for plant life.

*Are there microbes in soil?*

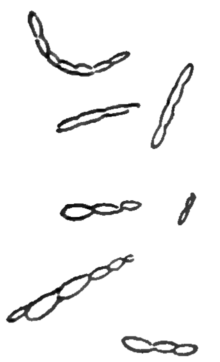
This is a chemical element called *nitrogen.* Nitrogen, mixed with other substances, helps to make up the bodies of all living things. But animals can obtain it only from plants. It is one of the gases of the air, but there it is wholly useless to all the ordinary plants, which can obtain it only from the soil in which they grow. As they grow, they use up the nitrogen in the soil, and it must be replaced in some way if the soil is to remain fertile. This is largely the work of the soil microbes.

This work is done in two ways. Certain

microbes are able to take the nitrogen from the decayed plant and animal matter, use it in their bodies, and then put it back into the soil, where it can be used by growing plants.

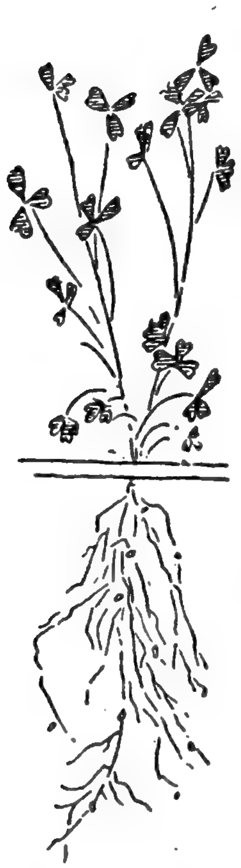
*What work do they do?*

The second, and by far the most important natural means of keeping the soil from "wearing out," is the work of certain microbes in securing the "free" nitrogen from the air. These soil-microbes grow on the roots of such plants as clover and peas and beans, forming small round balls, or *nodules,* which are filled with nitrogen. As if to pay for living on these roots, the soil-microbes give this nitrogen to the plants they live upon. In turn, when the plants decay, they leave the nitrogen in the soil, where it may be taken up by other plants.



*Nodules of a clover plant*

Farmers make use of this knowledge through what is known as *rotation of crops.* As plants such as wheat and corn have no soil-microbes living upon them, they take nitrogen from the soil. If a farmer planted wheat on the same piece of ground every year, the soil would soon be too worn out, by the loss of all its nitrogen,



*Clover plants enrich the soil with nitrogen* to produce anything. Instead of allowing this, the farmer plants wheat one year and the next year changes to some plant that will bring nitrogen to the soil. In this way he keeps the soil fertile, and does not need to fear that his land is "wearing out."

*How can soil be freshened?*

On farms where land has been completely "run down" by the continuous planting of such crops as wheat, tobacco, and cotton, it has been found that the growing of alfalfa will soon "build up" the soil. Alfalfa is a plant similar to clover and of the same family. It is a hardy perennial; that is, it does not "kill out" during the winter months. This enables alfalfa to send its roots far into the earth, where it may draw food from soil untouched by the average plant. As alfalfa is a nitrogen gatherer, its roots are soon covered with numerous nitrogen-factories —those small nodules which collect the free nitrogen from the air and deposit it later in the soil around it. In this way the soil is gradually freshened. Alfalfa grows naturally in most regions, but where it does not, the science of agriculture has successfully overcome the existing difficulties.

*What have microbes to do with decay?*

The work of taking the nitrogen from decayed materials and putting it back in the soil where it can be used by plants is done by two very different microbes. One kind does the first half of the job, and the second kind completes it. Only the first kind of microbe can start it, and the second kind can do its part only after the first is finished. It is a complicated job, but it is going on around us all the time. The next time you see some dead leaves rotting or a piece of food decaying on the ground, you will know what really is happening. These microbes are at work changing them into the nitrogen which makes it possible for plants to grow in the earth.

## Chapter V

# THE MICROBES THAT MAKE US SICK

*What microbes cause sickness?*

MICROBES of certain kinds cause disease. These microbes that make us ill are those whose food is living animal tissue, and that carry on their life and multiply in the bodies of animals and human beings. By their feeding on the substances of the body, they are capable of causing many different kinds of illness. Some can live in the bodies of animals without doing any harm, but when they get into the bodies of human beings they cause serious injury. Other kinds hurt only one part of the body and cause no harm in other parts, or they attack only at certain favorable times.

Some disease germs spread all over the body; they grow rapidly in the blood and tissues. In such cases the disease caused by their attacks is not centered at any particular point, but is at

*How do they cause sickness?*

work all through the body. Blood-poisoning is one of these diseases. Other germs settle in special parts of the body, and are unable to grow anywhere else. In either case, wherever the microbes live and multiply, they form poisons that are taken up by the blood and carried through the body. This is easy to understand when the microbes themselves are in the blood, but diseases where the microbes causing them remain in one place are like that, too. Diphtheria, for instance, is produced by germs that grow on the inside surface of the throat. The germs themselves do not enter the blood or any other part of the body, but, as they feed and multiply, they produce a powerful poison that is absorbed by the blood and thus goes all through the body. Sometimes, the microbes grow in the intestines and their poisons are absorbed from there. All disease-germs act in this way; they produce poisons which are absorbed by the body, causing the injury and pain known to be a result of whatever disease one is suffering with.

The ability of disease-germs to produce illness in a person depends also on a number of other things. The body has natural means of fighting these germs and killing them faster than they multiply. This we will explain later on. Only under conditions when the body cannot or does not fight them hard enough are they able to bring about sickness. One of these conditions is the age of the person. Children and old people become ill from some diseases much more easily than adults. Other conditions that help the growth of disease germs are hunger, thirst, fatigue, exposure to extreme heat or cold, a weakened physical condition caused by a previous illness, or some severe injury to a particular organ of the body.

*What can prevent them?*

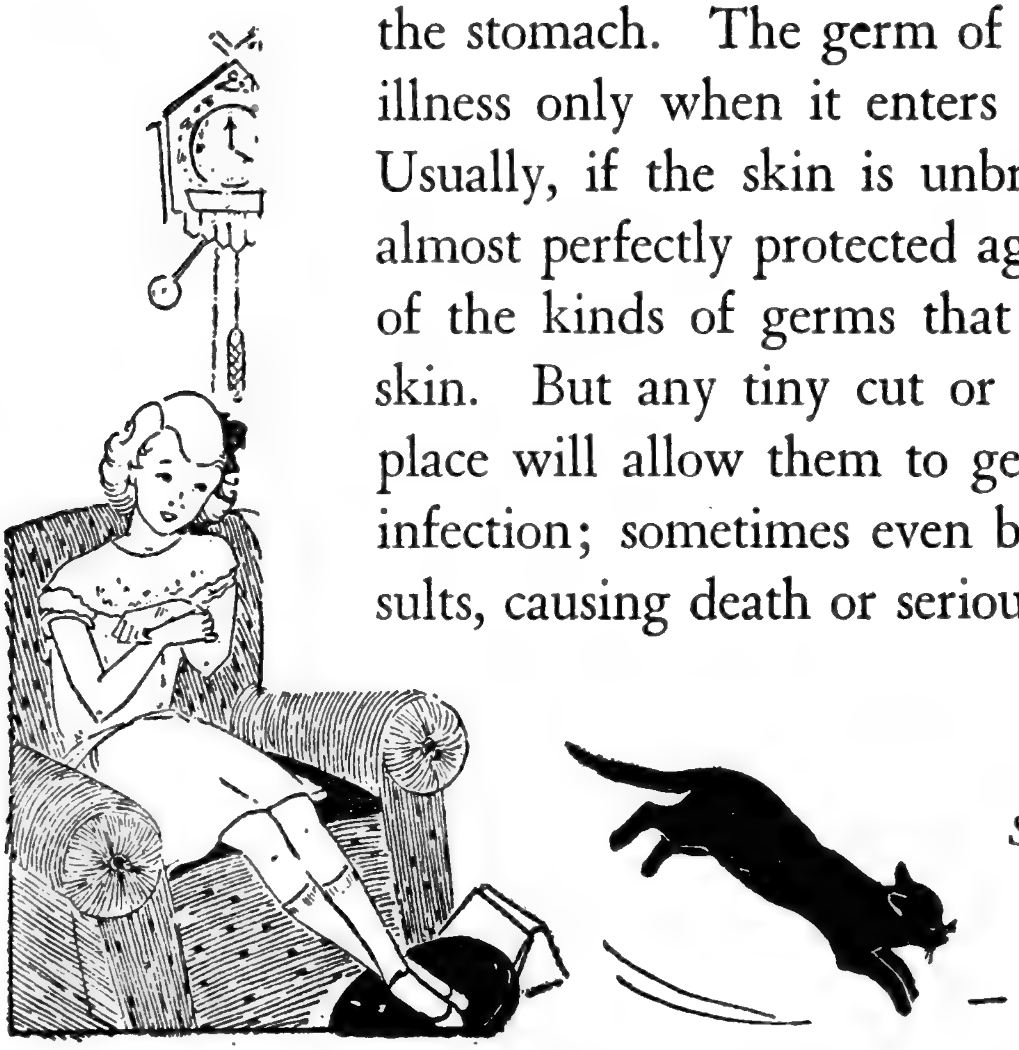
Not only does the condition of the body play an important part in deciding whether the disease germs can attack it, but the condition of the germs themselves is also important. At certain times their ability to grow in the body and produce injury there is less than at others. The number of disease-germs that find their way into the body is also important. Often the body can fight a small number of disease-germs, but the entrance of a large number will cause illness.

*How do they enter our bodies?*

Germs get into the body in many ways, and each germ may have its own favorite way of entering. Some kinds of germs can get in only one way, and if they enter in other ways, they cause no harm. But some of them, like the tuberculosis germ, cause trouble no matter how they get into the body.

*Blood poisoning microbes*

Some germs get in chiefly through the skin; among them are those that cause little sores or boils. These germs, however, are harmless in the stomach. The germ of lockjaw can cause illness only when it enters through the skin. Usually, if the skin is unbroken, a person is almost perfectly protected against the entrance of the kinds of germs that pass through the skin. But any tiny cut or bruise or skinned place will allow them to get in and cause an infection; sometimes even blood-poisoning results, causing death or serious injury.



*Scratches from pets may cause serious illness*

Many disease germs enter the body through the mouth and nose. Some, such as typhoid fever and diphtheria, get inside along with the food or drink that we swallow. Others we breathe in through the nose. The most important of these is tuberculosis; but diphtheria, whooping cough, pneumonia, and influenza may get into the body in the same way.

*How long do they live?*

As most disease-germs can grow and multiply only in the bodies of animals and human beings, they can live only a short time in the outside world. Some live longer than others, but few of them can multiply, except under special conditions, as when the typhoid or diphtheria germs get into milk.

Healthy persons, therefore, are likely to contract a disease only when they come in direct contact with a person suffering from it, or with matter containing the germs, which has recently been thrown off from the body of such a person. Most germs leave the body of a sick person by way of the mouth, nose, through the bowels; or as in smallpox or chicken-pox, by scaled-off skin.

*How can we guard against them?*

In diphtheria, for instance, the germs in the throat may be blown into the air by the person's breathing or coughing, or they may be left by the lips on a drinking cup. In tuberculosis, matter from the lungs passes into the mouth and then into the air by coughing and sneezing. In typhoid fever the germs leave the body through the bowels and thus get into the sewage, and from there sometimes into the water supply. So one can get typhoid fever from impure drinking water, and diphtheria from using a drinking cup that someone with diphtheria has recently used. By breathing air into which someone with diphtheria or tuberculosis has recently coughed, one can get either disease, without ever coming into touch with the person who is sick. But germs in the air live the shortest time of all, so that danger from this source is very slight, unless one is in the same room with the sick person. But it is necessary that people should always be on their guard against these deadly germs.

There is another means by which some

disease germs are carried that is really more dangerous than any of the other ways. It has been found that the germs of typhoid fever, diphtheria, and several other diseases, can live for a long time in the bodies of healthy people. After a person has had one of these diseases, the germs may go on living in his body for some time, and may be given off to other people whom this person meets. Healthy people sometimes get such germs into their bodies from a person who has them, and, while not happening to get sick themselves, they pass the germs to others who are not strong enough to fight the germs, and so they become ill. These *carriers,* as they are called, usually do not know that they have the germs, and it is almost impossible to know who these dangerous people are. But scientists and doctors believe that they are one of the chief means by which some diseases are spread.

*Do they affect all people in the same way?*

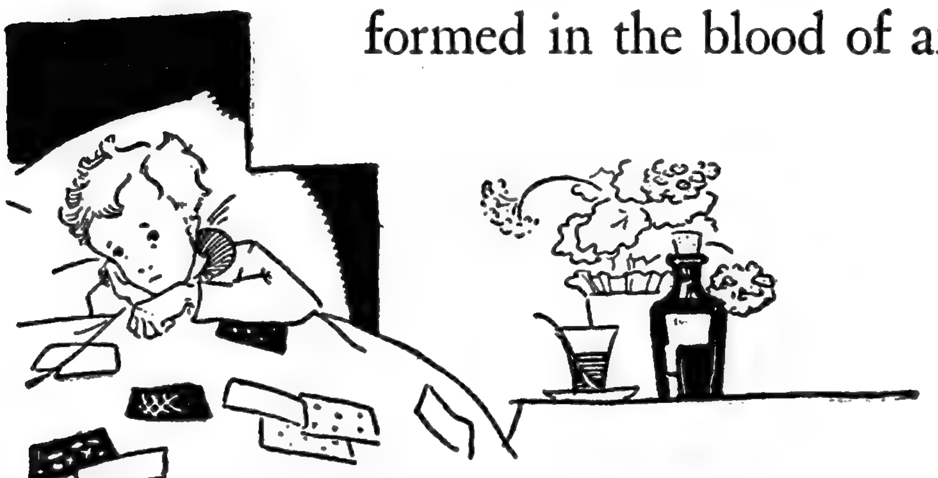
There are a few other diseases that are spread, not by germs from the bodies of sick people, but by being carried from one person to another by such insects as the mosquito. Malaria and yellow fever are the most common of these diseases.

*What does a diphtheria germ look like?*

The diphtheria germ, as we see it under the microscope, is slender and rod-shaped. It usually enters the body through the nose or mouth, and its favorite place for growth is the surface of the throat. It sometimes grows in the lining of the nose, but rarely gets into the lungs or into the blood. It attacks the tissues and gives off a strong poison which goes all through the body, often injuring the heart, the nerves, and the kidneys. The diphtheria germ more often attacks children than grown-ups, and is much more dangerous to them. It is often passed from a sick child to a healthy one through the use of a common drinking cup, the moistening with the tongue of a borrowed lead pencil, the exchange of handkerchiefs or candy or chewing gum or things like that.

*Diphtheria microbes*

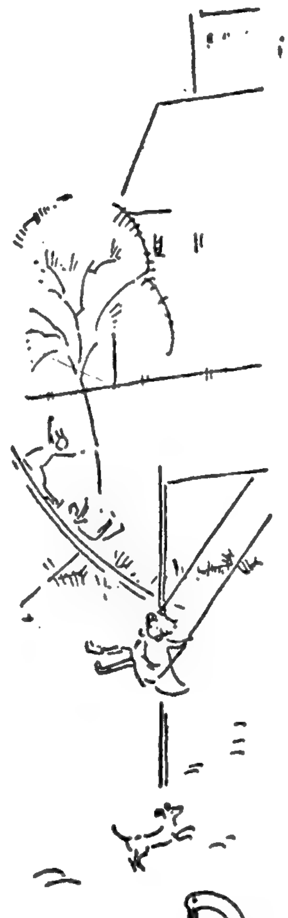
Diphtheria is usually cured by the use of diphtheria antitoxin. This is a substance formed in the blood of animals that have had

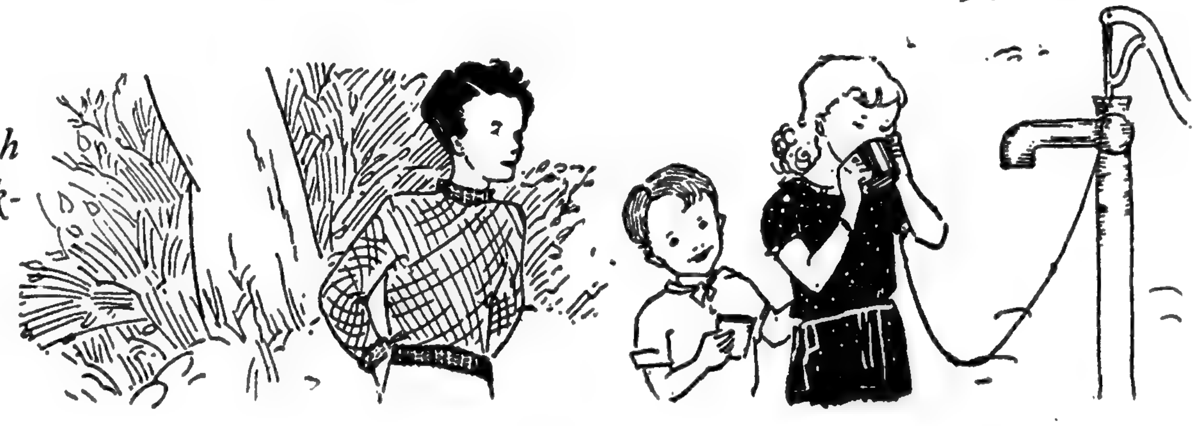


*Some microbes are harmful and cause sickness* to fight againts diphtheria germs that have been placed in their bodies. This will kill the germ in a human being who has the disease. It is forced into the tissues below the skin with a syringe, is absorbed by the blood, and attacks and kills the germs in the throat.

*What is antitoxin?*

The germ of pneumonia is round, but with a pointed end. It looks like a comma (,) and usually grows in pairs, sometimes in chains. There are some of them in nearly everyone's mouth and throat, but they do not attack the lungs and cause pneumonia except in certain cases. Perhaps the person's body has been weakened by some illness like measles or typhoid fever; perhaps the circulation of the blood is upset by a long or sharp exposure to severe cold, or perhaps the body has been weakened by some other cause. Then the pneumonia germ can do its deadly work. Babies and old people are more liable to get the disease than anyone else, because they are so often not strong enough to fight off the germ's attack. It usually attacks only the lungs,





*Microbes are spread through a public drinking cup* but sometimes it gets into the blood-stream. In such instances it nearly always causes death.

*What is a typhoid germ like?*

The typhoid fever germ is short, plump, and rod-shaped. It moves around rapidly with the aid of the tiny hairs (flagella) that are like a fringe around it. It is found outside the human body in streams, rivers, and lakes into which sewage is emptied, or in milk which has been handled by someone with the disease. It is not a very common disease nowadays. This is due to the putting of a purifying substance called *chlorine* into the water which city people drink, and the pasteurizing of milk, both of which kill the germ. But thirty years ago, in the United States, the records show that it caused 35,000 deaths, and that at least 350,000 people had suffered from it in a single year.

The typhoid fever germs enter the body through the mouth when a person drinks water or milk containing them. They attack chiefly the bowels, where they cause ulcers; sometimes they even eat holes through the walls of the

*Churning would be impossible without the help of certain microbes in the cream*

bowels. At the beginning of the attack, the person has a headache, loss of appetite, and weakness of the muscles, followed by a high fever. The germs do not remain in the bowels, but scatter throughout the body, entering the blood and tissues, during the illness.

*What is the tuberculosis germ like?*

The tuberculosis (or consumption) germ, as seen under the microscope, is a slender, slightly curved rod. Several of them usually lie in a small heap. They are among the most hardy of all the disease-germs, and can live outside the human body under unfavorable conditions for a surprising length of time. They withstand dryness very well. Masses of these germs in a cold, dark place will live eight or ten days. Boiling for five minutes kills them, and heating milk in a closed pan for twenty minutes at a heat of 140 degrees will destroy them there. Direct sunlight, with plenty of oxygen, puts them out of business in a short time, but great cold has little effect on them.

Any part of the body may be attacked by the tuberculosis germ, though the lungs are the most common place for them to settle. The bowels, the skin, the bones, and the joints are also frequently attacked. The germs do not enter the blood, but they cause growths which spread through the tissue of the place affected, and cause death if they are not stopped by the forces in the body that guard a person's health.

*Where do they come from?*

A healthy person may get tuberculosis germs by breathing air into which they have been thrown by the coughing, sneezing, or talking of a person having the disease. The danger of getting the disease is much greater in rooms, offices, or street-cars which are used by people suffering from it than it is in the open country or even in city streets. It can also be caught from a sick person by the use, in eating or drinking, of anything used by the sick person which has not been properly cleaned, so that some of the germs still stick on it.

But the tuberculosis germ, like the pneumonia germ, cannot harm the body unless something has happened which has weakened its ability to fight the microbe. Probably almost everyone who lives in a city, where there are so many germs of all kinds floating around, has inhaled or swallowed some tuberculosis germs, but it is only when one's body is weakened that they multiply enough to cause illness. Among the conditions that weaken the body so that the tuberculosis germs can no longer be controlled are: living in a damp place, leading an indoor life without healthful exercise, eating too little food, or the wrong kind of food, and working in a very hot or damp atmosphere. The disease, if discovered early enough, can often be cured by a change to a more healthful way of living, or in more serious cases, by moving to a dry, warm climate, like that of Arizona or California. Complete rest in order to leave all the energies of the body free to fight the germs, and plenty of fresh air and sunlight are the best remedies for fighting this dread disease.

*When do they cause trouble?*

Lockjaw is a disease that is marked by painful cramps in various muscles of the body, especially those of the jaw and neck. Hence the name. It frequently results from deep, dirty cuts or wounds, such as those caused by a rusty nail, or by the explosion of fireworks and toy pistols.

*What is lockjaw?*

This disease is the work of a slender, rod-shaped germ called *tetanus*. It is present everywhere in the soil, in dust, in mud, in water, and it grows without harmful effects in the intestines of horses and other animals. Human bodies are not its natural home; it gets into them only accidentally, and causes trouble only under special circumstances. It grows in deep wounds into which dirt, as well as other microbes, has been pushed. Its growth there depends on the presence of other microbes. It does not spread into either the blood-stream or the tissues, but multiplies in the wound itself and produces a poison which attacks only the nerves. The poison travels along the nerves to the central nervous system, where it causes the muscular cramps which betray its presence. Once the poison gets into the nerves, it is almost always fatal. But science has discovered an antitoxin for this disease. If it is applied to the wound very quickly, it will kill the tetanus germ before the germ has time to get very far. However, the use of the antitoxin is of little help after the germ has been in the body for more than thirty hours.

You can readily see the great danger in neglecting any deep and dirty cut. Such a cut should always be treated at once, in order to prevent the growth of this fatal microbe.

*What is malaria?*

Malaria is caused by a microbe that is an animal and not a plant, and is therefore different from the microbes that give us the other diseases that we have been talking about. It exists in almost all temperate and tropical climates. It is a strange microbe. It spends part of its life in man and part in a special kind of mosquito. It can live, therefore, only where there are mosquitoes. It gets into the blood-stream of a human being through the mosquito's bite. As soon as it enters the blood, the microbe attaches itself to the structure called a red corpuscle. It grows there and destroys the corpuscle. Then it breaks up into several new microbes, which attack other healthy red corpuscles in the same way. When the corpuscles break up, the person feels the chills and fever that are a sign of this disease. In the common form of malaria, the destruction of the corpuscles takes about two days; so the chills and fever are felt every other day. The use of quinine cures malaria, because it kills the microbes in the blood.

*How can we protect ourselves from malaria?*

We can protect ourselves against this microbe by the use of screens and netting to keep mosquitoes from biting us. They should also be kept from biting a person who has malaria, for the microbes in the blood then get back into the body of the mosquito and it can give someone else the disease. Fortunately, the most common type of mosquito cannot carry the malaria microbe, and so it is not dangerous. Only one family of mosquitoes can carry malaria, and of this one family, only those are harmful that have sucked the blood of a person having the disease. But, as we cannot always be sure which kind of mosquito is biting us, the only sure protection is not to give any a chance to bite us.

*How does the body fight microbes?*

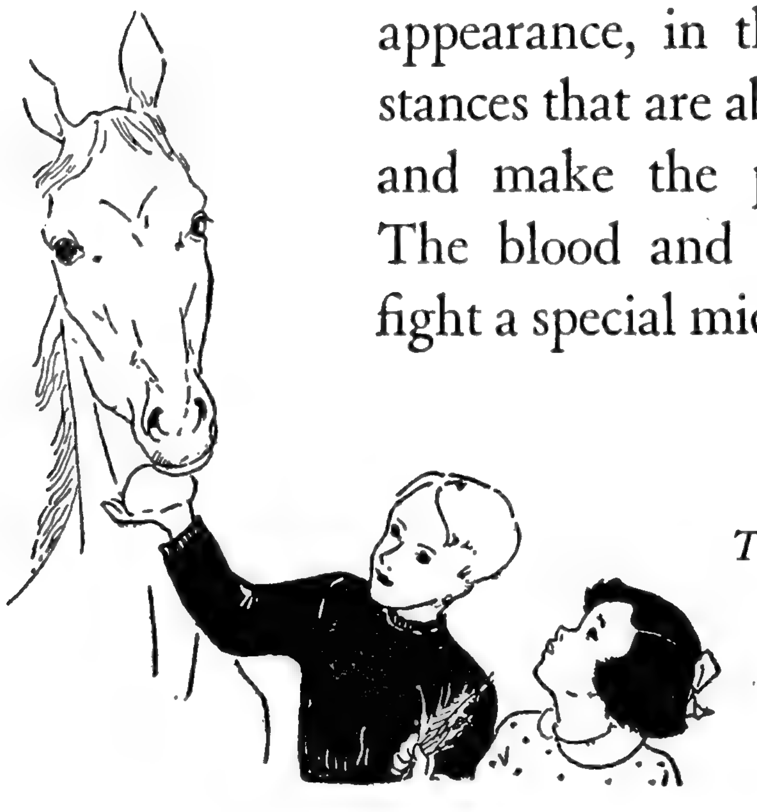
The body has several means of fighting harmful microbes. One of the principal means of defense is found in the blood. When we look at a drop of blood under a microscope, we find that it is made up of tiny red and white bodies swimming in a liquid. They are called corpuscles. The red corpuscles, which we have mentioned before, give the blood its color. In form, they are dish-shaped. They furnish the food for the tissues, and are used up in the tissues to give the body warmth. The white corpuscles are irregular in shape, and it is they that are the chief defenders against the invading microbes. Like the red corpuscles, they can move through the walls of the veins into the tissues and cavities anywhere in the body.

As soon as the disease-microbes invade the body, a whole army of white corpuscles rushes to the spot where the microbes are and begins a struggle with them. Each microbe is surrounded by the body of a white corpuscle and absorbed into it and digested. The white corpuscles really eat the microbes. Sometimes, however, the microbes are too numerous for the white corpuscles, or grow faster than the white corpuscles can eat them; then the microbes spread through the body and cause illness. These white corpuscles are always on guard in the body and are constantly at work destroying the harmful microbes that are trying to attack it. As long as the white corpuscles are stronger in the fight, and kill the microbes faster than they grow, we do not become ill.

*What do the white corpuscles do?*

An invasion of microbes in large enough numbers to produce illness causes the body to make other special efforts to fight them. It has been found that the coming of any kind of microbe into the body is the signal for the appearance, in the blood and tissues, of substances that are able to kill that kind of microbe and make the poison it produces harmless. The blood and tissues having this power to fight a special microbe are said to contain things

*Scarlet fever antitoxin*



*The horse helps in furnishing man with a cure for scarlet fever* called *antibodies.* The making of these antibodies is the reason why a person who has had measles or whooping cough, for instance, does not easily take the disease again.

*What are antibodies?*

The discovery of antibodies has also led to the inventing of ways to protect a person from the attacks of microbes, and to help cure the disease when it has appeared. It has been found that the antibody substance formed in the blood of an animal when attacked by a certain microbe can be placed in the body of a human being and will there protect him against the same microbe. Or, if he is already ill with the disease, it will help to kill the microbes in his body and bring about his recovery. When this is done, the substance transferred from the animal to the human being is called an antitoxin. We have already mentioned some of these antitoxins.

To obtain diphtheria antitoxin, the poison produced by the diphtheria germ is put into the blood of a horse. An antibody, or antitoxin, then grows in the horse's blood to fight the poison. Some of this blood is drawn from the horse's veins. Then, when a child is in danger from diphtheria germs, some of the antitoxin is injected into his blood. Thus the child is protected against an attack of diphtheria. The same thing is done to protect people against typhoid fever, smallpox, and many other diseases.

*Does the effect of antitoxin last?*

The protection given a human being by antitoxins taken from animals lasts only for a certain time, because the antibodies did not grow originally in his own blood-stream. But they do good work while they last, and they have saved many human lives, especially among little children.

## Chapter VI

# MAN'S FIGHT AGAINST MICROBES

*How long have we known about microbes?*

NOT until about two hundred years ago did anyone imagine that there were such things as microbes, and it was a hundred years more before anyone knew that they had anything to do with disease. Up to that time there were all kinds of queer ideas as to what made a man sick.

One of the earliest beliefs, and one that many savage tribes still have today, was that illness was caused by an evil spirit, or demon, which had entered the body of a man and caused trouble there. The only method of cure for a sick man was in some way to get the evil spirit to leave him. The medicine man, who was the primitive doctor, might try to persuade the spirit to come out, by prayers and promises; or an effort might be made to force it out, by the beating of tom-toms, or by pounding on the body of the sick man until the spirit was so uncomfortable that it had to leave. It is easily understood why nearly everyone who got sick died, when this sort of thing was the only treatment.

*What was "bleeding"?*

As men began to understand a little more about their bodies, another idea sprang up concerning the cause of illness. This idea, which lasted all through the Middle Ages, when terrible plagues often swept over Europe and killed millions of people, was that the body contained four substances—blood, phlegm, yellow bile, and black bile. Health depended on the proper mixture of these four substances, and if anything upset their proper mixture, illness followed. The efforts of doctors were spent in keeping this mixture correct, which is why they so often took blood out of sick people to cure them, for they thought there was too much blood in the body, and that this was what was making them sick. In the seventeenth and eighteenth centuries people had other curious ideas as to what caused sickness, all of them just as useless and stupid as the ones we have mentioned.

With such ideas about sickness, it is no wonder that a serious illness in those days nearly always meant death. Since men did not know what caused illness, or how it spread from one person to another, they could not know how to fight it. When plague appeared in a city during the Middle Ages, as it so often did, a person could only hope and pray that he would not get it. People had no idea that it was caused by germs that could be carried from one person to another.

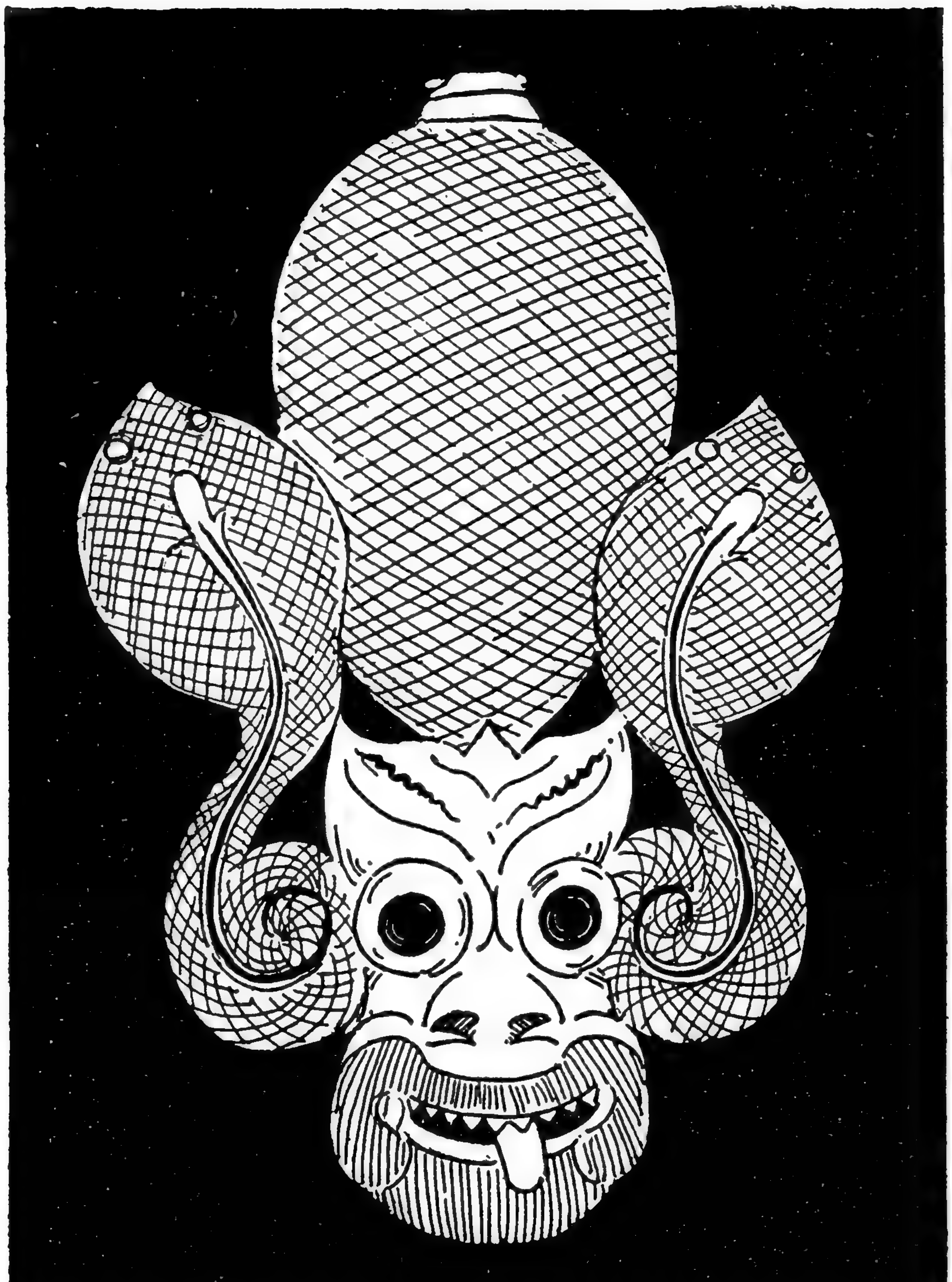
*What was the Black Plague?*

They did not know that the terribly dirty and unhealthful way they lived in the towns, crowded closely together in houses that were dark and overrun with rats, was a sure means of spreading disease germs. We know now that the worst disease they suffered from, the Black Death, is caused by a germ which is carried by rats, but they did not know it. So every now and then frightful outbreaks of disease swept the cities, sometimes killing nearly everybody. In the years 1348 and 1349, one-quarter of the population of Europe, or about 25,000,000 people, died of this disease.

*How did the discovery of microbes help us?*

It was only after the discovery of microbes and the studying of their actions that people began to learn the right way of fighting sickness. The part that microbes play in causing disease was found out only about fifty years ago. Though the existence of microbes had been known for a hundred years before, it was a great Frenchman named Louis Pasteur (living from 1822 to 1895), who first made clear to the world how microbes cause things to decay and ferment. Then, in 1876, Robert Koch, a German, showed that one kind of microbe was the cause of a certain disease, called *splenic fever,* in cattle. Koch also found a way to separate a single kind of microbe from a group containing many kinds, and to grow it in a pure state in the laboratory.

The work of these two men was the beginning of the scientific study of microbes, show-



*Primitive peoples thought that leprosy could be cured by wearing masks such as this*

ing their tremendous importance in the lives of human beings. The knowledge we have today of the causes of diseases, and of ways to prevent and cure them, is all based on Pasteur's and Koch's great and priceless discoveries, which have saved millions of human lives.

*What stopped work on the Panama Canal?*

When the United States first began to build the Panama Canal, white laborers were sent from this country to the tropical land of Panama to do the work. But so many of the laborers soon became ill and died with malaria, that work on the canal almost came to a stop. It became clear that unless a way could be found to keep the men from getting malaria, it would be impossible to build the canal.

Fortunately, a few years before, scientists had discovered that malaria is caused, as we have already seen, by a microbe that lives in the body of a single kind of mosquito. The mosquito, by its bite, spreads the germs from sick persons to healthy ones, who then become sick. The army engineers in charge of the work on the canal knew of this discovery; so they at once set to work to get rid of these mosquitoes, which were very numerous in the damp, warm climate of Panama.

*What did they do at Panama?*

They drained the stagnant ponds and swamps that were the mosquito's breeding places; they killed the young mosquitoes where they could not drain the water, by pouring oils and poisons on the surface. They also built houses for the workmen with mosquito-proof screens, and put mosquito-netting over the beds to keep the men from being bitten while they slept. Those who were already sick were placed in carefully screened hospitals to keep mosquitoes from getting in and biting the men who already had the disease. They thus kept the mosquitoes from getting germs and carrying them to men who were well. By the use of all these means, they were able to stamp out malaria almost entirely, and the great Panama Canal was built, uniting two great oceans, so that ships could pass from one to the other.

We can rightly call the building of the Panama Canal a modern miracle. It had taken years of labor and the best American engineering. Moreover, the Canal Zone had become a safe place in which to live. Man with a microscope had won. But at what great cost! Thousands of men and millions of dollars had been given in the battle with the mosquito before the American men began their work. However, if you go to the Canal Zone today, you will find a beautiful and healthful country made from what once was one of the most unhealthful places in the world. The people have learned to keep their land free of swamps where the mosquito once could grow so rapidly. Malaria is no longer feared. In fact, the city of Panama is one of the most healthful cities in the world.

*Do we know all about microbes?*

We must not imagine that we know all about microbes and their actions or that the fight against the attacks of disease-germs is won. To be sure, the world has learned many things about microbes. But there is much that is not yet known, and the fight is still being carried on. Many men in scientific laboratories in the colleges and universities, and in the hospitals

*How are these studies carried on?*

all over the world are spending their lives in studying the countless forms of invisible life and the ways in which they behave. Many wealthy people have given large sums of money to pay the cost of this work in the hospitals and universities. The Rockefeller Foundation, in this country, has a large laboratory for the study of diseases and the germs that cause them, and it pays all the expenses necessary for carrying on the work. It is probably the largest laboratory of its kind in the world. The Foundation also gives money to hospitals and universities to help them go on with their studies. Every day new things are being found out about microbes, and new ways are being discovered to prevent their attacking human beings and causing illness.

## Chapter VII

# HOW SOME FAMILIAR THINGS LOOK UNDER THE MICROSCOPE

THE microscope, with its enormous magnifying power, has not only made possible the discovery of all this world of invisible life around us. It has shown us as well, many things about the familiar living objects of the world we see that we could never have known otherwise. We have learned, through its use, what plants are made of and how they carry on their life processes. We can see the real structure of the hair and skin and blood of animals and human beings through it, and so find out how they perform their activities. The human eye is not strong enough to see all these things. So without the microscope we probably would never have learned the many things we know about how plants and animals live.

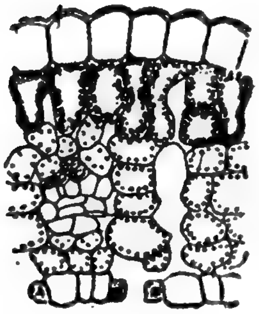
*What can we see through a microscope?*

You all know how a maple leaf looks, for instance. It is thin and green, with a ragged edge. There is a vein, or rib, down the center with smaller veins running out into the points. How different the same maple leaf looks under the microscope!

*What is a leaf like?*

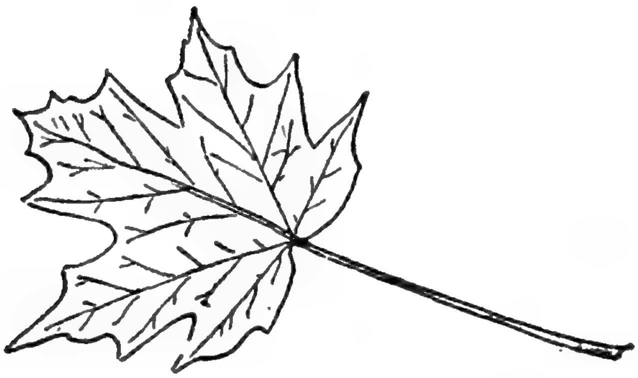
We usually cut the leaf in two with a razor blade and take a thin crosswise slice to put under the microscope. We find that the leaf has a rather thick skin on its top and bottom. In the lower skin we see little slits or openings that look somewhat like mouths. They are the openings through which the plant breathes, and through which any extra water in the plant escapes. They are rather like our pores through which we perspire in this respect, but they do the plant's breathing besides. All plants have to breathe, for they cannot live without air any more than human beings can. The plant has no lungs, however, and the air passes into and out of the plant body through these openings. They are called *stomas.* The oxygen in the air is used up by the plant for its life processes and carbon dioxide given off, just as in humans.

*Epidermis*



*Stomas*

*Section through a leaf*



*A maple leaf*

The stomas also regulate the water supply of the plant. If it is full of water, the lips of the opening will open and allow it to evaporate. In other words, the plant perspires. But if the plant is a little dry, the lips close up and no water is lost. The water which is necessary to plant life does not go in through these openings, however. Plants usually do not absorb water through their leaves, but only through their roots. It is taken in from the earth by the roots and rises through the woody fibers of the stem into the leaves. Then it passes out of the leaf into the air through the stomas.

*What is the inside of a leaf like?*

The upper skin has no openings. Between the upper and lower skins of the leaf are a great many irregularly shaped compartments called cells, with thin walls between them. They look somewhat like a honeycomb. They are crowded closely together just under the upper skin, but below are more spongy, with air spaces between them. Through this mass of thin-walled cells run little groups of thick-walled cells, which are the woody fibers of the midrib and other ribs. All the cells are lined with a transparent, slimy material like the white of an egg. It is called *protoplasm*. This protoplasm is one of the most important substances in plant life, for it is the bearer of life itself. It is found in all living things, and while its action is still very mysterious to us, it is essential to the life processes.

*What makes leaves green?*

Besides the protoplasm, the cells of the leaves are filled with water. Embedded in the protoplasm we can see innumerable tiny green grains, which are the substance which give the leaf its color. Each grain, under a more powerful microscope, looks like a tiny sponge dipped in green oil. This green coloring is necessary for the manufacture of all the food and building material of the plant—the starch and sugar and cellulose on which man and animals live. They are produced in these green grains from water and the carbon dioxide in the air with the help of sunlight, which furnishes the energy for the process. The leaf is the factory in which the whole plant is made and therefore the most important part of the plant. Plants truly live on air and water and nothing else, a thing no other living creature can do. Their water supply runs through the woody fibers from the earth into the stem and then into the leaf cells, and the air comes in through the openings, or stomas. From these two substances the plant manufactures its food.

*What is the nucleus?*

Sometimes we can see in the thin-walled cells, full of water and green grains and protoplasm, a little round body which is called the *nucleus*. This nucleus may be said to be the brain substance of the cell, in which its life functions center. If we want to make the nucleus easier to see, we can stain the cell with red or blue dye. The nucleus will absorb more color than the rest of the cell and thus stand out clearly.

This is what the maple leaf looks like when we cut it through crossways. If we want to see what the skin looks like from above, we can lay a transparent young leaf flat under the microscope and look at it that way. When we look at the under side, we find that the skin, too, is made up of little oblong, stretched-out cells with thin walls. The stomas look even more like human mouths. They are long narrow openings with a cell on either side which looks like a lip. There are usually many fine hairs on this lower skin. Each hair is a single tube-like cell, or series of cells, connected to a flat cell in the skin. These hairs form the fuzzy surface we so often see on the backs of leaves.

*Why are the tops of leaves waxy?*

When we turn the leaf over and look at the top skin, we find that it has no hair and no stomas. It is composed of long flat cells which have a shiny surface of wax. The wax prevents the rain from staying on the leaf and protects it against the evaporation of water through the cell walls.

We have to shave a thin slice from a pine wood chip in order to examine it under the microscope. When we look at it we see that it, too, is made of long, narrow cells with rather thick walls. The cells extend up and down in the trunk of the tree, and they have pointed ends which fit closely together. There are peculiar little windows in the walls between the cells. The regular wall is replaced by a fine skin, and, in order to protect this skin, a sort of saucer covers it on both sides. Each saucer has a hole in its center. These windows are called *pits*. They allow the water to pass from one tube, or cell, to another and so up through the trunk into the leaves. The cell walls are made of woody fibers. Sometimes we find them reinforced by a spiral band, like a spring, which is coiled about the outside of the cell wall. The cell walls are the framework of the tree or plant. They support the tree and through them the water is transported to the leaves. These cells and cell walls are built up by the process which takes place in the leaves. The trunk or woody part of the plant is actually manufactured in the leaves from air and water, with the help of the sun.

*What does wood look like?*

If we shave off a piece of wood crossways, instead of up and down, and look at it that way, we see that the cells are often perfectly round.

We also notice that there are rings of rather large cells with thin walls and then rings of smaller cells with thicker walls which alternate from the center to the edge of the trunk. They make the wood look light and then dark colored. These are the annual rings by which we can tell the age of the tree. The wood formed in the spring has larger cells with thinner walls, while that formed in the fall has thick walled smaller cells. Each ring of thick walled cells represents a year in the tree's life. By counting them we can tell the age of the tree.

*What are the rings in wood?*

The cells are a little different in the woods of different trees. "Hard" woods like maple and oak have thicker walled cells, which contain more woody substance, while "soft" woods like pine and spruce have thin walls and much less woody fiber.

Botanists have found that there are several different kinds of roots. Some plants have roots which merely hold the plant down to the ground and absorb the water it needs. Other plants have roots from which the new plant sprouts and grows, instead of growing from a seed as most new plants do. Many plants can produce new plants both ways. They have roots from which new plants sprout and they grow seeds from which new plants will grow. One of the most common of the plants which belong to the last group is the potato.

*How does the potato look?*

The potato is a root. Its main object is to store food for the young plants which may develop from its eyes or buds. If we look at the soft juicy tissue of the inside of the potato under the microscope, we discover that it contains chiefly starch. Globes of the starch are stored in the many thin-walled cells of the potato. The globes themselves consist of innumerable layers, like those of an onion, around a solid center which is not in the middle of the grain but usually near one end. Sometimes two or more grains grow together. When we want to see these thin layers more clearly, we stain the starch grain with iodine, which turns it blue. In many of the cells there is a little protoplasm and even a nucleus in addition to the starch grains.

*Starch grains*

*Potato with buds*

*The potato is a root which contains starch*

*What are the eyes?*

When we cut open one of the little eyes in the skin of the potato and look at it through the microscope, we find that it contains tiny leaves. It is really a bud. When the potato is put in the ground, these little leaves sprout out and grow into a new plant. If, after the buds have sprouted in the ground, we take the potato out again and examine it, we find that the starch has disappeared from the cells. It has been used for food by the young plant while it was developing green leaves of its own with which to manufacture its food.

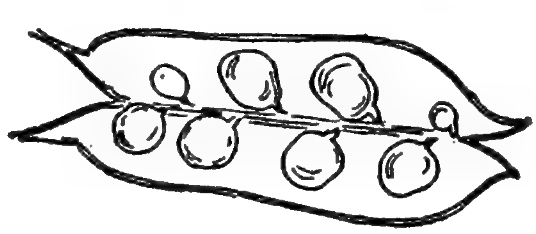
The roots of trees and flowers do not have this storage place for new plants, for they grow from seeds instead of from the roots. Their roots are only fine tubes of woody fibers, covered with fine hairs. The hairs attract the water in the earth in some manner we do not quite understand. Then the water is sucked into the tubes of the roots, where it rises into the stem and the leaves. Such simple roots as these also hold the plant down to the earth, so that it does not blow away in the first breeze.

Let us take a common kind of seed and see what the miscroscope can tell us about it. A fresh green pea is an excellent one to examine. When we cut it open and look at it under the microscope, we find that it contains a tiny plant. Inside the thin skin which covers it is a little root, a small stem, and two leaves, all folded together and practically filling the skin. The little leaves are green and made of rounded thin-walled cells. The cells are filled with starch, droplets of oil, fine grains of a whitish material known as *albumin*, and some green coloring grains. It is really a pea plant in miniature, with the food stored near it to feed it until it grows into an independent plant.

*What is inside a green pea?*

The green pea itself is not grown up, however. If it were allowed to develop, instead of being picked when it is fresh and green, the pod would finally dry up and burst open. The pea would be hard and dry, too, not at all like the soft tender green one we looked at. It would fall to the ground, and the moisture there would cause it to swell up and become green

*Pea pod*



*Open pod*

*Germination peas*

again. The little rootlet would burst out of the skin covering and fasten itself in the ground, the stem would raise up and the leaves pull out of the skin and at once begin to manufacture food. The food we saw in the leaf cells would be used up very rapidly in the first few days and even hours of the seedling's growth, but by the time it is gone, the leaves are big enough to make their own food.

*What is pollen?*

In order to get a seed which can produce a new plant, it must first be fertilized. This is done by *pollen.* Pollen is the yellow or brown powder which we see in the hearts of flowers or in the catkins of poplar or willow trees. When the wind blows, this yellow dust is shaken from the flowers and falls on the immature seeds and fertilizes them.

When we look at a grain of pollen under the microscope, we see that it is a very tiny round or oblong cell with thick walls. The walls often have designs or bristles on them and sometimes there are wings attached to them which act as sails. The cells are filled with protoplasm and a great deal of oil and starch. They also contain a nucleus. The pollen grain contains the most concentrated form of plant substance, for in it many of the qualities of the future plant lie dormant. The addition of the material in the pollen to the immature seed makes a seed which can grow and produce a new plant.

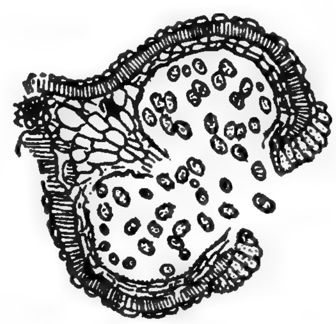
*How is it carried about?*

The pollen grains are carried to the immature seed by insects as well as by the wind. When a butterfly flits from flower to flower, it carries pollen dust on its feet and wings, and so does the bee. The bee also uses the pollen it gathers from the flowers to build its hive. It mixes the oily contents of the grain and its thick skin into a paste or wax, much as the modern building contractor mixes concrete. But that is diverting the pollen grain from its real use, which is to fertilize young seeds and make it possible for them to grow into new plants.

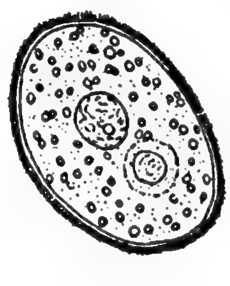
When we pull a single hair from our heads, we find there is a little oily bulb on the end. Under the microscope this bulb looks rather like an onion, for it is made up of many thin layers.

*Lily*

*Pollen as seen through the microscope*



*Pollen escaping*



*Pollen grain*

*What does hair look like under a microscope?*

The bulb is deeply embedded in the skin and from its bottom grow fine nerves and blood vessels which nourish it. We never pull all this root out. Some of it remains in the skin and from it grows a new hair which is invisible at first but slowly pushes its way through the skin to the surface. The inner portion of this bulb, or root, is the true living portion of the hair which grows. The long thin hair above the skin is dead. It consists of a long thin tube filled with air. The tube also contains grains of red, brown, yellow, or black coloring matter, which is called *pigment.* This pigment is what gives the hair its color. It usually disappears with age and the hair grows gray and then white.

The outside of the hair, which looks perfectly smooth to us, under the microscope has innumerable wavy cross-lines on it. The hair of a cat, dog, rabbit, or any other animal is even rougher looking than human hair. It has all sorts of fine crisscross and zigzag lines on it so that sometimes it even looks like a bamboo or a palm tree trunk. A person who has studied hair under the microscope can recognize the hair of any animal by the markings on it without being told what animal the hair came from.

*How does skin appear?*

From above, a piece of our skin shows a rather irregular surface, under the microscope. There are numerous small openings to little sweat glands in it and many tiny hairs stick out. The skin looks greasy and wrinkled and not at all like the smooth skin we see with our naked eyes. If we could slice off a piece crossways, as scientists have done, and examine it, we would find that the skin has a hard, horny, almost transparent outside layer. Under this protective layer is a softer layer of tiny cells and below that, cells of the fat and tissue that form the body. The soft middle layer has many deep sockets in it in which are embedded the roots of the hairs. Through it run little tubes which are the sweat glands.

In the cells just under the outside layer are little grains of the same kind of coloring material as is in our hair—pigment. When there is only a little pigment, the blood shines through the outer layer of skin and we have a fair complexion. If there is more pigment, we are brunettes. Strong sunlight on the skin makes these grains of pigment become darker, so that if we have a great deal, we tan in the sun. If we have pigment only in spots, we freckle, and if we are very fair, with almost no pigment in our skins, we simply sunburn. For the pigment, besides coloring our skin, protects it from burning in a too hot sun.

*What is complexion?*

The skin on the lips has no horny outside layer. It is just a fine thin layer of cells through which the red color of the blood is very visible.

## CHAPTER VIII

# THE MICROBES' GREATEST SERVICE TO MANKIND

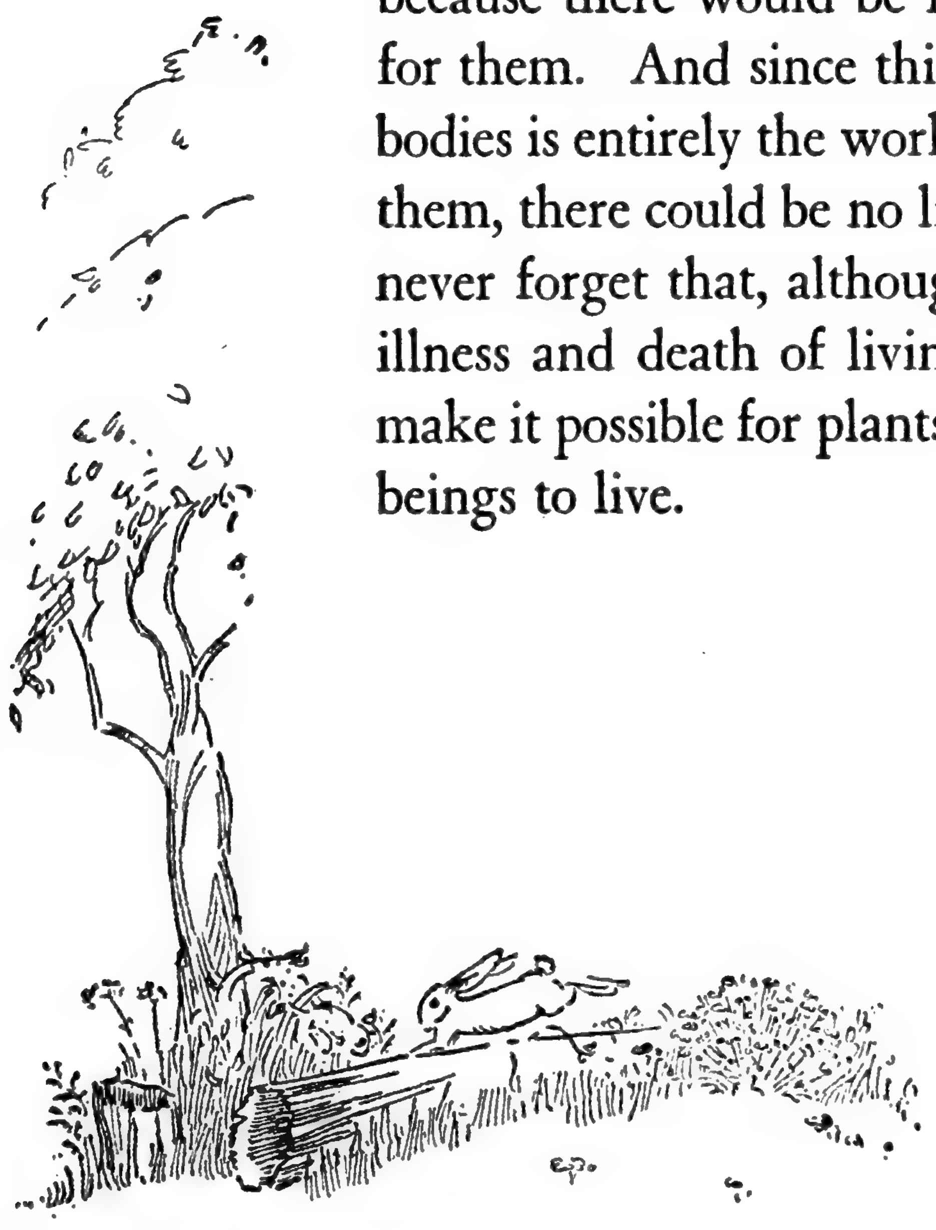
WE so often think of microbes as the cause of all kinds of dread diseases, that we almost forget their useful services to mankind. Besides the work that they do in fermentation, helping us to make butter, cheese, vinegar, bread, and other things, there is another job they do that is the greatest of all. This is the decay and destruction of dead animal and plant bodies.

*What is the greatest work of microbes?*

Here, microbes, while satisfying their own need for food, are playing a necessary and important part in the world's work. Plants and animals use as their food, lifeless material taken from the air, from the soil, and from living things, and transform it into the substance of their bodies. When they die, all this material would remain in a form that other plants and animals would be unable to use as food. Here is where the microbes do their greatest service. They break up the dead bodies into materials that become once more a part of the air and soil, where they can be used to feed new living things.

*What would happen if there were no microbes?*

This decay is going on everywhere about us all the time. If it did not take place, the dead bodies of plants and animals would soon pile up on the earth and no living things could exist, because there would be no food or even room for them. And since this breaking up of dead bodies is entirely the work of microbes, without them, there could be no life on earth. So let us never forget that, although microbes cause the illness and death of living creatures, they also make it possible for plants, animals, and human beings to live.



*A most useful work of microbes is causing decay*