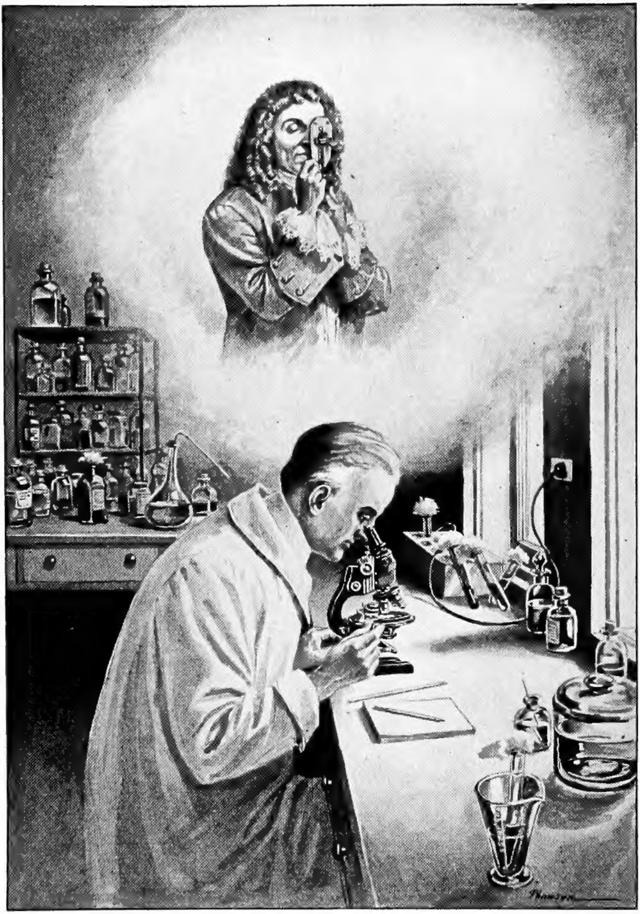
BACTERIA, YEASTS, AND MOLDS IN THE HOME

CONN



THE OLD AND THE NEW

The modern bacteriologist, as he looks through his up-to-date research microscope, might well give a grateful thought to Leeuwenhoek, who in 1683 discovered bacteria with *his* microscope, a crude affair consisting of two screws, a copper plate with a hole in it, and a single lens mounted in that hole.

BACTERIA, YEASTS, AND MOLDS IN THE HOME

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THIRD REVISED EDITION

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PREFACE

At present it is necessary for those expecting to become housewives to understand the elementary phases of a number of sciences, most prominent among which are chemistry and bacteriology. The relation of microörganisms to household affairs is now felt to be one of the most important phases of domestic science. The present work is designed for all interested in household affairs, including not only students in domestic science but all housewives who are interested in keeping their homes in the best and most healthful condition.

The present (third) edition has been quite largely revised in order to bring the subject up to date. The principal changes made relate to refrigeration, canning, and the spread of disease. The book has further been changed by adding a historical introduction in order to give the student an idea of the historical setting of the subject and at the same time to introduce it in a way to arouse as much interest as possible.

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SECTION I—INTRODUCTION

CHAPTER I

HOW OUR KNOWLEDGE OF MICROSCOPIC LIFE BEGAN

The mother of a large family of children well knows that she has her hands full in keeping them out of mischief. Generally by the time the children have grown up she feels she knows as much on the subject as anyone; and quite possibly in a practical way she does, even in these days of specialists in child feeding, children's diseases, child psychology, and other studies relating to children. If she lives in the country her household may include cats, dogs, and possibly other animals, and she knows that keeping them in their proper places is almost as much of a task as it is with her own children.

But what about the invisible members of the household, the **bacteria**, **yeasts**, and **molds**? Does she often stop to realize what a problem they can be? They are omnipresent; they are capable of doing more mischief than a cat in the larder, more actual harm than a vicious dog; they cannot be taught obedience like a child or a dog; nor can they be thrown outdoors like a cat that is in the way. They are too small to be seen and can be recognized only by what they do; and for such tiny creatures they can do a lot, either for good or for bad. The housewife has to learn something about them in a practical way whether or not she knows anything about their actual nature. She has to know that milk will sour if it is kept warm; while if she bakes her own bread she must know that the dough has to be warm or it will not rise. Such practical information as this is possible without realizing that bacteria sour milk or that yeasts cause bread to rise; but there is no question that she can control bacteria and yeasts more intelligently if she knows something about the habits of these tiny beings.

These microscopic beings, commonly known as **micro-organisms** or, more popularly, as microbes or germs, are minute plants consisting of the three groups — bacteria, yeasts, and molds — each of which is the subject of one of the later sections of this book. They have been with mankind since the earliest days. Some of them have always been spoiling our food or even bringing sickness upon us; others, in a less conspicuous way, have been benefiting us by acting as scavengers or by furnishing food for our crops or by giving desirable flavors to some of our foods. But the human race lived for thousands of years without knowing of their existence or realizing how much more comfortable life on earth could be if we became acquainted with our microscopic friends and enemies. This acquaintance actually began only about seventy-five years ago; and during that brief period man has made more progress in conquering the ills that flesh is heir to than since human life on earth began. Nevertheless, even in the earlier days mankind had learned how to control some of the activities of microörganisms, although without suspecting that there were any such creatures; and one of the first practical lessons in their control was probably made by a housewife.

It is a question whether the housewife or the wine-grower was the first to obtain practical knowledge of microörganisms.

It was known in prehistoric times that grape juice would ferment into wine and that dough would rise on standing, and one can only guess as to which discovery was made first. This much, however, is beyond question: back in the days when wine-making was still an uncontrolled process, yielding a somewhat uncertain product, some housewife had apparently discovered a crude method of cultivating yeast and controlling the process of bread-raising. She seems, therefore, to deserve more credit than the wine-maker in the matter; and one cannot question that her product has been of more value to mankind than that of the vineyards.

We suppose that the following must have happened. The early cooks discovered that dough became more palatable if allowed to stand in a warm place overnight, or possibly longer, before baking. This simple process may have been followed for centuries before any attempt to improve it was made; although it must have been noticed repeatedly that some batches of bread were better than others. Some batches would be light and sweet, others heavy, and others sour. The important discovery came when some cook who had a lot of dough rise unusually well decided to save a little of that lot without baking it and to add it to the lot she was going to make the next day. Much to her delight she found that in this way she could insure good batches of dough every day. The method was simple enough, and was followed by other cooks until it became well known, although no one dreamed that she was actually cultivating a microscopic plant. The small portion of dough saved over to raise the next batch was called **leaven.** That leavening dough was a common accomplishment in early days is shown by the casual references to it in the Bible, such as the well-known passage

"Know ye not that a little leaven leaveneth the whole lump?" No important improvement in this process was made until after the middle of the nineteenth century, when scientists had discovered with their microscopes bacteria and yeasts. Then they found out how to isolate the yeast plant from leaven; and for the first time were able to teach the housewife something about bread-making. The modern yeast cake is a product of the scientific laboratory; and its common use to-day is one illustration of the way science can assist the housekeeper in controlling the invisible members of the household.

The Discovery of Bacteria

It is not certain who first saw bacteria, but the credit is sometimes given to a Roman Catholic monk, named Kircher, who in 1671 used simple lenses of high magnification to examine various materials such as pus, decaying matter, blood, and water. He mentioned the discovery of "invisible worms" in this material and wondered if they could be the cause of disease. It is very doubtful if he really saw bacteria, for his lenses were of very low magnifying power as compared with our modern microscopes; and his idea that they might have anything to do with disease was a mere guess. Yet it is interesting to know that the existence of microscopic organisms was recognized so long ago and that their production of disease had been suspected.

Only about twelve years later, however, there is even better reason to believe that bacteria were really seen. At this time (1683) a Dutchman, Leeuwenhoek, saw microörganisms, described them, and drew pictures of them; and some of his sketches look very much like actual bacteria.

Now Leeuwenhoek was not a scientist in the modern sense of the word. That is, he did not spend his time in the laboratory and earn his living by scientific work. No one did in those days. There was no such profession open to any one in the seventeenth century; and most of the advances in scientific knowledge made at that time were made by monks or men of leisure who dabbled in science or by men in some business pursuit who were curious about nature and studied its secrets in their odd moments. Thus Leeuwenhoek, besides some regular trade, had a minor position in one of the public buildings of Delft; in addition to all this he became interested in making lenses and learned how to grind better lenses than any one had before. He finally made them so small and of such high magnification that it required a special holder for the lens in order that he might see anything with it. The lens was in the round hole near the top. The platform and screw were for holding the object to be examined; the microscope was turned toward the light, the eye placed behind the lens, and the object mounted on the platform was examined (see Frontispiece).

It seems hard to believe that anything as small as bacteria could be seen with such a crude microscope; and yet we do not know what else the objects may have been that he described. Examining material scraped off the teeth, he exclaimed: "With greatest surprise I saw that everywhere in this material many very tiny animalcules were to be found, which moved around in the most surprising fashion." He noticed how abundant they were in water and commented on the enormous number we must swallow in the water we drink. His chief reaction was one of amazement that there could be so many and so very small living beings.

It is hardly surprising that some one in these early days should have guessed that these minute creatures, which must enter our bodies with our food and drink, may have been the cause of disease. In fact, the first guess of this kind was made as early as 1546 by one Fracastorio of Verona, who had never seen any microscopic organism. In spite of this fact, he proposed a germ theory of disease quite like what we believe to-day, except that he had no idea what sort of creatures his "living contagious bodies" might be. Two centuries later (1762) an Austrian physician, Plenciz, was able to go further than this, for it was known by that time that microörganisms really existed and that there was more than one kind of them. He suggested, in fact, that each disease might have its own specific microscopic agent which could cause that disease and no other. He explained that these microscopic bodies could be distributed through the air, enter the body and live there, producing the disease, and believed that they might then spread to other hosts by means of discharges from the body. Plenciz's theory was not generally accepted in those days. It was, of course, based on pure speculation; and neither he nor his followers could obtain evidence to prove it. So the theory fell into disrepute; and as late as 1820 it was casually referred to as an "exploded theory."

The Origin of Life

When a housewife cans a lot of vegetables or fruits, she is confident that if the canning is well done, the contents of the can will not spoil. If she is intelligent, she knows that means that she has killed the microscopic organisms present in the food and has sealed the jar so tightly that no more microörganisms can get in. But how would she feel if she believed that these tiny creatures could spring to life spontaneously in any organic material without having to get in from the outside? Naturally she would think her canning might be unsuccessful no matter how carefully the work was done.

And yet that is just what was believed in the eighteenth century. It was not supposed that these tiny organisms needed any living parent; in other words, scientists believed in **spontaneous generation.** They thought, in fact, they were being very conservative in limiting this possibility to microscopic organisms; for at an earlier day it was generally believed that even moderately large animals could come into existence without living parents. In the ancient days we find even intelligent writers giving directions for producing mice. All you had to do was to put a piece of cheese in a dark cellar, cover it with rags, and in a few days the cheese would have turned into mice! The results of this experiment would often be the same to-day if we selected a cellar not too tightly constructed, although we should have a slightly different explanation as to where the mice came from. As a matter of fact, long before the eighteenth century all serious-minded people had given up the idea that creatures as large as mice, eels, or worms could arise spontaneously; but only very recently it had been believed that meat turned into maggots. It took a very clever scientist to think of keeping meat screened so that flies would not get at it and then to observe that the maggots did not appear; this same scientist (Francesco Redi) studied the maggots and discovered that they were immature flies. From that time on

(1688) maggots, as well as mice and eels, were understood to need living ancestors. Redi even went further and made a statement that was not by any means proved by his observations, and which was indeed quite startling to his contemporaries; he claimed, in fact, that life comes only from life.

Nevertheless, the belief in spontaneous generation still persisted. Microscopes had shown that decaying liquids were full of minute living creatures. It was observed that if any organic liquid was kept for a few days, even in a tightly stoppered bottle, these microscopic beings were sure to appear in it. Where did they come from if they did not spring spontaneously into life within it? Of course we do not believe this to-day; if we did, we should not be so confident that we can save food by canning it. But for about a century and a half the subject was very hotly disputed.

About the middle of the eighteenth century a scientist by the name of Needham tried to settle the question by boiling an infusion of meat, or something of similar nature, in order to kill all living things in it; he then sealed it hermetically in the vessel in which it had been boiled and set it aside to see what happened. Any housewife who has tried to can some vegetable, which does not contain much sugar or any acid, by the open-kettle method (or even by the cold-pack method if the jars were merely allowed to stand in boiling water) has a fairly good idea of what is likely to happen in such cases. She knows that her vegetables canned in this way often go bad; in fact, they practically always go bad unless she allows them to stand in boiling water for a few hours. So Needham found that although his boiled infusions sometimes remained clear, they were very often filled with living organisms after standing a few days. He believed that these must have developed spontaneously in the liquids. He had plenty of followers in this conclusion; for the idea was quite in accord with the views of the day.

Meanwhile another school of scientists, led by Spallanzani, vigorously opposed Needham and his school. They claimed that if sufficient pains were taken to kill all the microörganisms, none would develop, and they carried on experiments to prove their point. The dispute continued unsettled until about the middle of the nineteenth century. On one side it was claimed that those who obtained evidence of microscopic life in boiled infusions did not carry on the experiments carefully enough; on the other side it was claimed that heat changed the nature of the liquids so that microörganisms could no longer develop until air was admitted. It seems strange, indeed, that anything so obvious to us to-day should have been under dispute among eminent scientists for so many years.

Oddly enough, the question was settled in a practical way while this dispute was still raging. Early in the nineteenth century (1809) a Frenchman, Appert, discovered that if perishable food was placed in proper containers, sufficiently heated and afterwards **hermetically sealed**, it would keep without spoiling. Appert was, in fact, the founder of the canning industry. Now it was realized even in those days that the spoilage of food and the development of microscopic organisms in it went hand in hand; and if any scientist had stopped to think about it, he would have realized that Appert was successfully keeping living things out of his jars of preserved food. That this can be done is immensely important to any housekeeper; and it plainly could not be done if microscopic life could originate spontaneously in any suitable food, no matter how carefully all microörganisms had been excluded from it.

Scientists did not regard Appert's methods of canning food as being scientific proof of their point, however. It was not till about 1860 that proof to suit the Needham school was furnished. One of those who helped furnish this proof was Pasteur, the founder of **bacteriology**, an undoubted genius, and such a genius that authors never tire of writing about him. We must give more than passing attention to his work, of which his refutation of spontaneous generation was a very small part. He accomplished this in a very simple and yet conclusive manner. He made a glass flask with a long neck drawn out into a long and crooked tube. The contents of such a flask were exposed to the air, which could pass into the flask without even having to pass through a filter. Yet no microscopic particles, either living or dead, could be blown through the long crooked neck, and any such object falling into the end of it would surely lodge at the bottom of one of the bends. Pasteur showed that, if the contents of such a flask were heated hot enough, they could be kept free from microörganisms for a long period; although, on cooling, the contraction of the air in the flask must suck in a good quantity of air from the outside. Some of these flasks prepared by Pasteur are still preserved, and the contents are still sterile after these many years. He also showed that if the neck of a flask were broken off short so that dust particles could settle into it, the contents would become cloudy in a very few days and would show the presence of microscopic organisms. After this demonstration by Pasteur no one was able to convince scientists that spontaneous generation was possible.

CHAPTER II

HOW THE IMPORTANCE OF MICROÖRGANISMS WAS DISCOVERED

Louis Pasteur, born in 1822 in the family of a simple French tanner, was destined to become one of the most picturesque and most famous men of the nineteenth century. His keen scientific mind led him to explore new fields hitherto uninvestigated, and thus he became one of the world's leading scientists; while his great depth of feeling led him into those phases of science which gave most promise of relieving suffering, and he may well be considered one of the greatest benefactors to mankind that the world has ever known. Not many of his discoveries had a direct bearing on household problems; but indirectly they are of importance in every home, and every one should know about him.

Pasteur began his career as a chemist, and he gave promise, while still a young man, of becoming one of the leading chemists of his day. But he happened then to get interested in **fermentation**, not dreaming that in this way he was headed away from chemistry. The study of fermentations was a part of chemistry in those days, and it was not until Pasteur himself had founded the science of bacteriology that any one thought of the two subjects as distinct.

His study of fermentations brought him into direct controversy with one of the most prominent chemists of his time, the German, Liebig. The history of bacteriology is full of controversies between the French and the German scientists; Pasteur, it will be seen, started the fashion even before bacteriology had really come into existence. The name of Liebig is best known to the housewife to-day from the beef extract that bears the name; but his real reputation is in far different fields. He was, without question, one of the greatest chemists of the middle of the century. By the time Pasteur began his work, Liebig had won, and thoroughly deserved, an outstanding reputation. It happened, however, that he made one mistake; and Pasteur was successful in pointing out Liebig's error. Liebig had scoffed at the idea that the microörganisms seen in decaying organic matter were the cause of the fermentations taking place; he insisted that fermentation was a purely chemical process that took place in organic matter if conditions were right, just as combustible material in which a flame had once started would continue to burn by purely chemical action. Others before Pasteur had shown that such material would not decompose if it was sterilized and the microörganisms kept out but that the fermentations would begin as soon as they were introduced. Liebig could easily answer such an argument by saying that just as a pile of wood could not burn until the conflagration had been kindled by a small flame, so organic matter would not begin to decompose until the process had been started by the spontaneous decomposition of the dead bodies of these microörganisms. This answer convinced every one for many years; Liebig was too great a man to oppose lightly. But Pasteur proved that he was mistaken. He showed that the same material could undergo different kinds of fermentation, that each was associated with a different kind of microscopic organism, and that he could bring about whichever type of fermentation he desired by introducing the proper kind of "yeast," as he called all such microörganisms.

The housekeeper should remember this. Milk, she well knows, ordinarily sours with a smooth, firm curd. Occasionally, however, the curd produced is full of bubbles and has a cheesy odor. On rare occasions milk may go bad without curdling at all; while if kept in an air-tight container it may decompose in such a way as to smell like rancid butter. Each of these types of decomposition is due to a different kind of microörganism; and it was Pasteur who first realized this. Pasteur's demonstration of the fact completely disposed of Liebig's theory of fermentation.

Pasteur regarded this work as a mere side line, and planned shortly to get back to his chosen field. But the Fates willed differently. For at about this time (1865) France was quite suddenly threatened with the loss of one of its chief industries, silk-raising, on account of the ravages of a disease among the silkworms. This disease, known as **pébrine**, had baffled some of the best minds of France, and its ravages were becoming so serious as to cause widespread alarm. Then some one thought of Pasteur, and he was asked to study the problem. He hesitated for some time; for he foresaw that if he went so far afield in his work he might never get back to chemistry. But he finally agreed. And he solved the problem — not in a day, or a month, or a year even, but soon enough to save the silkworm industry. It took him five years, and discouraging years they were, too — saddened by the death of his daughter, an attack of paralysis which left him lame for the rest of his life, a burst of skepticism which greeted his discoveries when first announced, and finally by his country's defeat in war with Prussia. To overcome the skepticism and to prove that he had actually controlled the disease, he finally had to hire a silk farm which had been abandoned on account of pébrine, and to show that he could bring it back into healthy condition again.

Thus Pasteur saved the silk industry for France; but better yet, he had proved the germ theory of disease. For a century or more it had been guessed that diseases might be caused by germs; now Pasteur had proved it. This discovery led to the study of other diseases, and even more important results were brought about. The first of these diseases was **anthrax**, an extremely serious disease of cattle and sheep. Pasteur conquered this disease by showing how to inoculate animals against it.

Vaccination for anthrax was an entirely new idea at that time. Smallpox vaccination had been known for half a century, ever since the famous discovery of Jenner. Dr. Jenner, a physician practicing in the latter part of the eighteenth century, had happened to hear a remark by a country girl: "I can't take smallpox because I have had cowpox"; and from that had been born his idea of intentionally inoculating people with cowpox to prevent their getting smallpox. As a result, this most dreaded disease of the eighteenth century had been almost wiped out from civilized Europe before the time of Pasteur. So vaccination was well known to Pasteur's contemporaries; but who had ever heard of vaccinating for anthrax?

Pasteur would not have thought of trying it if he had not made an accidental discovery along the same line several years before. In the early '70's he had been working with a disease of poultry known as **chicken cholera**, which he had concluded was caused by some microörganism. He had a culture of this organism, in fact, and used it again and again to produce the disease in healthy fowls. But one time, on returning to his laboratory after a vacation, he found it had lost its power of causing the disease; but before learning the fact he had inoculated several chickens with it. He then obtained a fresh culture, and much to his surprise discovered that although it would produce the disease in other chickens, it had no effect on those which had been inoculated with the old culture. This was the accidental observation that has nearly revolutionized the practice of medicine. To a mind less keen than Pasteur's it might have merely suggested that these particular chickens were "tough old birds" not susceptible to the disease. But no such explanation satisfied Pasteur; he wondered why they were not susceptible, and immediately made the right guess — they had become immune because he had first inoculated them with an old culture, one too weak to cause the disease. Thus he concluded that an animal could be made immune to a disease by inoculating it with a weakened culture of the organism causing that disease. That is probably what is done in the case of smallpox vaccination. Cowpox is probably a modified form of smallpox, weakened by passage through cattle and no longer capable of giving a human being a real attack of the disease, but capable of making him immune. This possible identity of cowpox and smallpox is still nothing but a guess; but here in the case of chicken cholera Pasteur had shown definitely that a weakened culture could give **immunity** without causing the disease. It was a momentous discovery, not because chicken cholera is a disease of much importance, but because the same principle could be applied to other diseases.

He first applied this same principle to anthrax. In this case he found that old cultures were just as virulent as fresh ones; but he soon discovered that he could weaken the anthrax germ by growing it at a high temperature. A culture weakened in that way could be used to vaccinate cattle against the disease. He proved this to his own satisfaction; but he had found other scientists so skeptical about his earlier discoveries that he decided to arrange a public experiment to show that he had conquered anthrax. For this purpose he obtained fifty sheep, and in the presence of an assembly that had come to watch the experiment he inoculated them all with virulent anthrax bacteria. Now, anthrax is a severe disease, and any sheep thus inoculated could hardly be expected to escape; but, as Pasteur informed the crowd, twenty-five of the sheep had been vaccinated against anthrax and were immune. He urged the assemblage to return in two days to see the result. On the third day, therefore, a large crowd, composed of farmers, physicians, veterinarians, scientists, and journalists, was present, and their impressions of the sight that greeted them were so strong that the world is never likely to hear the last of Pasteur's experiment. Twenty-five sheep were dead or dying; the other half of the fifty were in perfect health. The success of the vaccination was perfectly demonstrated.

Thus far Pasteur's discoveries had not saved a single human life, while Jenner's one discovery had saved hundreds of thousands. And yet Pasteur had really made a discovery of greater value to mankind than Jenner's. This is true even though smallpox had been one of the worst scourges of the seventeenth and eighteenth centuries, while anthrax was a disease of sheep and cattle rarely attacking human beings. Jenner had made a chance discovery and did not know how to apply the same method to the attack of other diseases. Pasteur, on the other hand, had reasoned out the control of anthrax from a theory already in his mind, and since the theory had worked once, there was no reason why it could not work again. And it has; disease after disease has since yielded to a similar line of attack. The first human disease to be conquered in this way was **rabies**; and again it was Pasteur who made the conquest. He is said to have attacked that disease first because of a horror of hydrophobia which had persisted in his mind ever since losing a boyhood friend by this disease following the bite of a rabid wolf.

He used the same principle to control rabies that he had with anthrax, but his methods had to be different. After experimenting in various ways, he finally discovered that if he removed the spinal cord of a rabbit dead of this disease, it would cause the disease in another animal; but if dried under certain conditions for a number of days, the germs in it lost their virulence and yet caused an animal inoculated with them to become partly immune so that fresher material could be used without producing the disease. In this way Pasteur found that an animal could be made immune to rabies.

He supposed that the treatment would also work on a human being. But his problem was far from solved. Consider the difficulties still ahead. Who would undergo the risky experience of being vaccinated against rabies on the bare chance that some day a mad dog might bite him? Or if he had agreed to be vaccinated, would he let a mad dog bite him so that Pasteur could test his theory? Hardly! Pasteur's only hope of making the treatment a practical success was the possibility that it would be effective if applied *after* the bite. That seemed illogical; but the long period which elapses between bite and appearance of symptoms made him hope that such might be the case. Fortunately his hope was justified, and the treatment to-day is used in just that way.

But Pasteur did not know the treatment would work if applied after the bite, and the only way to find out was to try it. To try it he had to apply it to some one who had been bitten by a rabid dog, and the only way to secure such a patient was to announce the treatment to the world. He hated to do this, for he was afraid it would prove a failure. But he announced it, and felt he had staked his reputation on a very uncertain hope. To make things even harder for a man of his sensitive nature, his first patient was a little boy, who had perfect confidence that the famous Pasteur would keep him from getting sick. Pasteur had the boy live with him during the treatment, and no patient was ever watched more closely. When the time for the appearance of symptoms came around Pasteur could hardly sleep, but was up at all hours to watch for the slightest sign of sickness. By this time it was much more than the success of his experiment and the effect of its failure upon his personal fame that concerned him; he had become genuinely attached to the little boy and was praying with all his heart that he might be saved. The boy lived. All the world to-day has heard of those sleepless nights of Pasteur and how he finally became convinced that either his treatment or some unknown miracle had saved the boy. To-day the Pasteur treatment is used so generally that we know it was no miracle; human ingenuity had conquered a dreaded disease.

While Pasteur in France was making these discoveries, Germany also produced a bacteriologist who achieved international reputation, Robert Koch. Koch has never been called the father of bacteriology; but he made great discoveries. He learned the cause of tuberculosis, among other things; but in another way he made a still greater contribution, which the public has never appreciated. Bacteria are such tiny objects that, when they were discovered, it was a puzzle how any one could ever study them. You cannot pick one up with your fingers or even with the tiniest forceps made; you can barely see it with the highest-powered microscope. It took a genius like Pasteur to study them. Then Koch showed a simple method. To be sure you cannot handle a single bacterium; but Koch showed how you could fasten it down on a plate of jelly so that it could not move and its descendants could not swim away from it until finally a mass of bacteria (a **colony**) developed large enough to be seen with the naked eye. There was something large enough to handle; you could not pick up a single organism, but you could make a culture from one of these colonies, and if the work were done carefully you could be reasonably sure that the culture contained the descendants of one organism only. That simple little method revolutionized the study of bacteria and opened up the field to any one who wanted to explore it.

Some of these new students were French and some were German. The rivalry between the two schools became even more intense as discovery after discovery was made, first in one country and then in the other. It was at its height, perhaps, when **diphtheria antitoxin** was discovered. Here the honors were very evenly divided. A Frenchman, Émile Roux, first discovered that diphtheria germs produce a poison which we call **diphtheria toxin.** His work was quickly followed up by Behring, a German, who, by the use of this diphtheria toxin, actually produced antitoxin on a small scale, enough to cure a small animal, but hardly enough to be of practical value to a human being. Then Roux went further and produced it on a practical scale.

Discoveries came rapidly thereafter. The first bacteria to be studied were naturally those of disease, because every one was afraid of diseases and wanted to see mankind rid of them. But later other kinds of bacteria were given attention. Even before Pasteur's day it had been learned why milk soured; but now it was learned how to keep it sweet and how to prevent other foods from spoiling. It was found that bacteria are everywhere, and that no household can be run in such a cleanly way as to exclude them. Many of these discoveries have practical value to the housekeeper. Since she has bacteria around her on every hand, since they may be mischievous or may be among her best friends, it behooves her to learn how to keep these invisible members of the household under control.

CHAPTER III

MICROÖRGANISMS IN THE HOUSEHOLD

Thanks to these discoveries it is now well recognized that bacteria, yeasts, and molds together form a group of utmost importance in human welfare. Although far too small to be seen, their rapid rate of reproduction makes them one of nature's strongest forces either for weal or for woe. Their importance in connection with disease and the practice of medicine was recognized many years ago; and a little later their significance in agriculture was understood. Still more recently it has come to be appreciated that their relation to the ordinary household, and hence to the housewife, is even more intimate than to the physician. We are learning that many of the tasks of the housekeeper, some of which may be more or less unpleasant, have their foundation in bacteriology, and we are beginning to recognize that these microörganisms constitute the foundation of the demand for cleanliness so forcibly emphasized in modern times. Thus the vague knowledge of the past is growing into a scientific understanding of the subject.

In the household microörganisms have an important bearing in three directions:

1. They are the cause of the **decay** and **spoiling** of foods and many other products.

2. They are sometimes of value in the **preparation** of foods.

3. They are the cause of **contagious** and **infectious diseases.**

1. Microörganisms and the Preservation of Food

Although household duties are varied in character, the larger part of them concern the preparation and the preservation of foods. The *preparation* of food belongs primarily to the department of cooking, although certain other factors are concerned. But the science of cooking has little to do with the *preservation* of food. This latter problem is intimately related to modern bacteriology. It is largely for this reason that the study of bacteriology and kindred subjects has in recent years come to be looked upon as a part of the necessary training of the housewife.

At the outset we may properly ask, Why is it that food *spoils?* Why will not food keep indefinitely without the many contrivances designed to prevent its spoiling? The answer to this question is, briefly, that other living things besides ourselves are fond of the same foods of which we are fond, and that these other living beings take every occasion to consume the material which we design for our own food. Preserving the food in our pantries, cellars, and refrigerators, therefore, simply means protecting it from consumption by other living organisms; and if we can keep these organisms away, food may be indefinitely preserved. On the other hand, if we cannot protect our food from the attack of these organisms, it spoils; for the spoiling of food is simply the result of its consumption by living beings for whom we have not designed it.

The living beings that endeavor to consume our food comprise, in the first place, some of the larger animals with which every one is familiar. Every one knows about rats and mice, and the various insects in the home are only too familiar pests. But not every one understands that in addition to these large animals there is a great host of plants and animals which seize every opportunity of feeding upon that which we intend for our own use. All such small animals and plants go by the general name of **microbes** or **microörganisms.**

We are chiefly concerned, in this book, with three important groups of plants. Some of these plants are large enough to be seen easily and are generally well known, such as the molds that occur everywhere, and are always regarded as nuisances in household economy. In addition to the visible plants there is a still larger number of others, quite too small to be visible to the naked eye and, indeed, only seen with the high powers of the microscope. These invisible organisms are the smallest living beings of which we have any knowledge, and are both friends and foes. Not only are they invisible to the naked eye but to the ordinary housewife they are quite unknown. Until within recent years they have been unknown even to scientists, and although science has now learned to understand quite well what they are and what they do, to the public in general they are little more than a name around which cluster various mysteries and in regard to which there is no general information. **Molds** and **yeasts** have long been known. The term **bacteria** refers to organisms which began to claim public attention much more recently but in regard to which there is at present a large amount of misunderstanding. Even though these organisms are very minute, and though she knows little about them, the housewife finds them the most serious, indeed the only serious foe with which she has to contend in her attempt to keep food in proper condition for use.

These invisible plants are constantly on the alert to consume for themselves the foods which the housewife designs for the table. If they have a chance to get at the food, she soon notices that it undergoes a series of changes, characterized by what we call **putrefaction, decay, souring,** or perhaps some other change not properly classed under any of these terms. The general rotting of fruit, the decay of meat, the souring of milk, and a host of other similar phenomena which occur in every pantry if the food is not carefully protected, represent some of the effects produced in foods when microörganisms begin to feed upon them. Thus it is evident that these microscopic plants play a very great part in domestic economy. This fact, however, has not been thoroughly appreciated until recent years, and indeed it is only just beginning to be recognized to-day that the housewife's knowledge should comprise an understanding of the nature and habitat of these microscopic foes, their methods of distribution from place to place, the conditions under which they grow and fail to grow, together with the various devices which may be adopted for checking their active growth where they are not wanted. Although the facts have only recently been appreciated, it is known to-day that a very considerable part of the duties in every household is concerned with these microscopic organisms, known and unknown.

The chief desire of the housewife is to prevent the growth of these microörganisms in places where they are not wanted. For this purpose have been invented refrigerators and all devices for cold storage and for cooling and keeping cold any food products; to this end, too, are designed the various methods of preserving food and fruits. The immense industry of canning, either on a large scale as is done in factories, or on a small scale as is done in the household, is dependent upon the relation of microörganisms to food. The sterilizing or pasteurizing of milk, as well as other foods, is also a bacteriological problem, and, indeed, many other phases of household life are really bacteriological phenomena. Whether or not she possesses a scientific knowledge of bacteria and their allies, the housewife must have a certain practical knowledge of their nature and of their powers, for this practical knowledge is absolutely necessary to enable her to preserve her food successfully from the microörganisms which are so liable to spoil it.

2. Microörganisms as Useful Agents

It must not be understood, however, that microorganisms are always our foes. It is true that in the household they are commonly a source of trouble, but it is also true that some of them are distinctly friends. To appreciate that they are sometimes useful, even in our foods, one needs only to remember that under this head are included the great group of yeasts that play such an important part in the household in the raising of bread and in all types of fermentation. Yeasts, as well as bacteria, are microscopic plants, of which the microscopist recognizes many kinds. Some of these are troublesome, but, so far as concerns their relations in the household, they are usually servants rather than undesirable foes. Even bacteria, which are in general looked upon as dreaded foes, and as agents only of evil, are, under some circumstances, our friends rather than our enemies. Bacteria, for example, produce the delicate flavors in butter and the stronger but equally delicious flavors of cheese. Bacteria also are solely responsible for the manufacture of vinegar; for although vinegar might be made by chemical means, the vinegar of our tables is produced by the agency of bacteria. Molds also, though generally looked upon as unmitigated nuisances, are, in some places, of decided use. The utility of molds, however, has little to do with household products, being confined chiefly to the production of certain types of cheeses. The flavor of Roquefort cheese, for example, is due chiefly, if not wholly, to the growth of certain types of molds within the cheese. These illustrations will serve to show that microörganisms, even in the household, must occasionally be looked upon as friends rather than enemies.

3. Microörganisms and Disease

Certain species of microörganisms are harmful to human health and are the cause of contagious diseases. They are generally known as **disease germs** or **pathogenic bacteria.** Fortunately they are few in number. While large numbers of species of microörganisms may be troublesome in the household because of their action upon our foods, very few species, comparatively, are able to do harm in the human body or to produce disease if they should find entrance. The great majority of species are, then, harmless to human health, but a small number are capable of producing disease, and for this reason are of especial interest.

The study of the causes and cure of disease belongs primarily to the physician and not to the housewife. The housewife must, it is true, occasionally act as the nurse of persons suffering from contagious diseases, and will then be interested in the treatment of the patient and the cure of the disease. But even here the question of cure must be left to the medical profession, while as nurse she should simply follow the directions given. Yet one phase of the matter is almost solely hers, for to her must be left the task of preventing the distribution of contagious diseases. Many of the diseases produced by microörganisms are distinctly contagious and, unless the patient and the other members of the home are properly guarded, a disease is likely to be carried through a household from one person to another. To prevent the distribution of such contagious diseases is the duty of those who care for the home.

In preventing the distribution of diseases the primary problem is a bacteriological one, for, since microörganisms are usually the cause of the disease, the prevention of contagion is the prevention of the distribution of bacteria. In every home such problems are more or less common. They concern the members of the home far more materially than they do the physician. Every household will occasionally have experience with contagious diseases, and the question of preventing their distribution from a patient to a healthy individual is sure to arise. The housewife who cares for the home year after year will have many experiences where a knowledge of distribution of diseases is of even more importance to her than to the physician himself. The physician is directly concerned in the cure and only indirectly in the prevention of contagion; the housewife must always have upon her shoulders the duty of keeping her family in health, and when an instance of contagious disease appears she must try to protect the rest of the household. For these reasons it follows that a knowledge of disease germs is of more vital significance to one who cares for the home than it is to the physician, who is only concerned in curing the disease. The physician or the Board of Health may give suggestions and directions, but the successful application of these directions depends upon the intelligence of the home keeper.

This brief outline of the relation of bacteria to various household problems is sufficient to show why a knowledge of microörganisms should be a part of the equipment of any one who is to conduct the affairs of a well-regulated household. For the development and preparation of some foods, for the preservation of all foods, and for the protection of the health of those under her care, the head of a modern well-equipped home needs to understand bacteria and kindred organisms. A knowledge of molds, yeasts, and bacteria has become a vital if not a necessary part of training in domestic economy.

Different Classes of Microörganisms

Nearly all the microörganisms with which we are here concerned have this characteristic: they are what botanists call **colorless plants.** This does not mean that they are absolutely without color, for they may be bluish, reddish, gray, or white, or, indeed, they may show other colors; but it means that they do not have the green color characteristic of the majority of plants in nature. The absence of this green coloring makes them unable to live upon the food in the soil, and forces them to live upon a kind of food different from that of ordinary plants. Ordinary green plants can live upon minerals which they obtain from the soil, and upon gases which they obtain from the air, but the colorless plants cannot use such materials at all. They need a more complex type of food.

The materials in nature are frequently divided into **mineral** and **organic** substances. Mineral, or inorganic, substances are such materials as rocks, sand, earth, etc. Organic substances (wood, bones, fruit, muscle, etc.) are those which have been produced by animals or by plants, i.e. by *organisms*. Evidently the foods we eat — meats, fruits, vegetables, etc. — are organic, since they all come from plants or animals. Colorless plants, such as **fungi** and **bacteria**, are, like animals, obliged to have organic substances for foods, and therefore feed upon materials essentially similar to those which form the food of animals, i.e. meats, fats, sugars, etc. Since the colorless plants and the animals are in need of the same kinds of food they become rivals in nature. The green plants, on the other hand, living upon totally different foods, are in no sense the rivals of animals, but their allies. It is this fact, their living upon organic foods, that makes the colorless plants of so much importance for good or ill, and explains their close relation to the problems of the household with which we are concerned.

Among the colorless plants are a great variety of forms which show wide differences in structure, size, and general appearance. But inasmuch as they all agree in lacking green coloring material, they are, at least from the standpoint of their relations in nature, properly placed in one general class. A method of dividing them, convenient for our purposes, is as follows.

Colorless Plants

Higher Fungi. This includes the forms of larger size, known generally as *mushrooms*, *toadstools*, *wood fungi*, *rusts*, *smuts*, etc. With these plants we are not particularly concerned in the household.

Molds. Fungi of small size, but yet easily visible to the naked eye, composed of threads.

Yeasts. Microscopic plants which multiply by a process called *budding*, composed of oval bodies.

Bacteria. Still smaller plants that multiply by a process called *fission*, composed of spherical, rod-shaped, or spiral bodies.

This classification is not scientifically accurate. The **higher fungi** include a large number of different types classed by botanists into many subdivisions. But since they are not concerned in household problems we may most conveniently group them together and consider them no further. Scientists also classify yeasts and bacteria still further into smaller groups; but one does not need to learn them to understand the behavior of these micro-organisms in the home.

The group of **molds** also is not a proper scientific division, since under this head are included several different kinds of plants which botanists agree must be separated into several divisions. Some of the so-called molds really belong to the higher fungi. But though the term "mold" is not a good scientific one, practically it is very useful. It is a common English word, quite generally understood, and always refers to a variety of plants characterized by a general appearance so well known as to be easily recognized by persons who are entirely unfamiliar with scientific botany. Although admitting that the molds do not represent any real scientific division of fungi, we may use the term as referring to colorless plants which every one recognizes but which cannot be scientifically defined.

The other two groups, **yeasts** and **bacteria**, are proper scientific divisions.

In our study of household problems we are concerned only with molds, yeasts, and bacteria.

PROTOZOA

One or two diseases referred to in later chapters are caused by animals rather than plants. Malaria is certainly so caused, and possibly smallpox. These animals are unicellular and belong to the group **Protozoa**.

SECTION II — MOLDS

CHAPTER IV

THE GENERAL NATURE OF MOLDS

As intimated in the last page, the group of molds does not form a scientific division. Among the plants grouped under this popular name are included representatives of several different groups of fungi. The general character of molds is a dense mass of fine white threads. But some of the higher fungi related to the toadstools produce a white threadlike mass, and if we find this growing in abundance upon the surface of wood we commonly call it a mold. Other so-called molds belong to the different subdivisions related to cup fungi, *Ascomycetes*, while still others belong to an order of fungi which includes parasitic plants like rusts and smuts, and are called *Æcidiomycetes*. We must not, therefore, look upon molds as a division which would be recognized by any botanist. For household purposes, however, no term can take the place of this one, so universally known and so thoroughly understood. In our studies, therefore, we shall group together as molds all types of fungi which produce white felted threads, which have the power of growing in or upon food materials, and which give rise to the well-known appearance that characterizes the plants going under this common name. Most of them are closely related to each other.

The general appearance of molds is well known to every one. At first they are soft, fluffy masses, usually white, though later they may become blue, green, brown, black, or red. They grow upon all sorts of material and, under some conditions, with very great rapidity. A typical mold as it appears to the naked eye is shown in Fig. 2. The molds which are liable to appear on the foods in the household are by no means always alike, though the housekeeper rarely recognizes any difference between them. They differ in many respects, — in the fineness of the threads of which they are made, in the rapidity of their growth, in the materials upon which they grow, and more particularly in color; for while most are white at first, they show many other colors later. The most common of the household molds is one which at the time of fruiting becomes a bluish-green color, and hence is called the "blue mold," *Penicillium glaucum* (see Figs. 1 and 5). This species is common upon bread and cheese, but it will grow upon

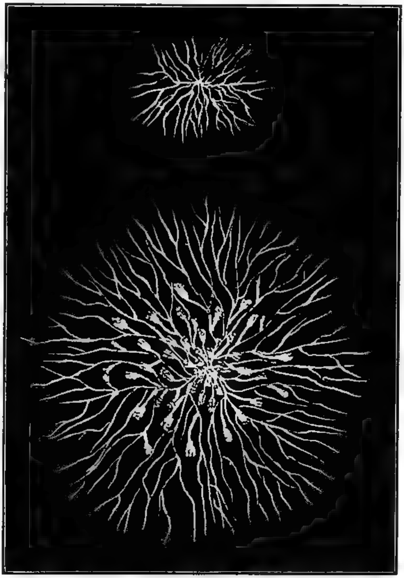


FIG. 1. Two colonies of common mold, *Penicillium*, as shown under the microscope on a black background.

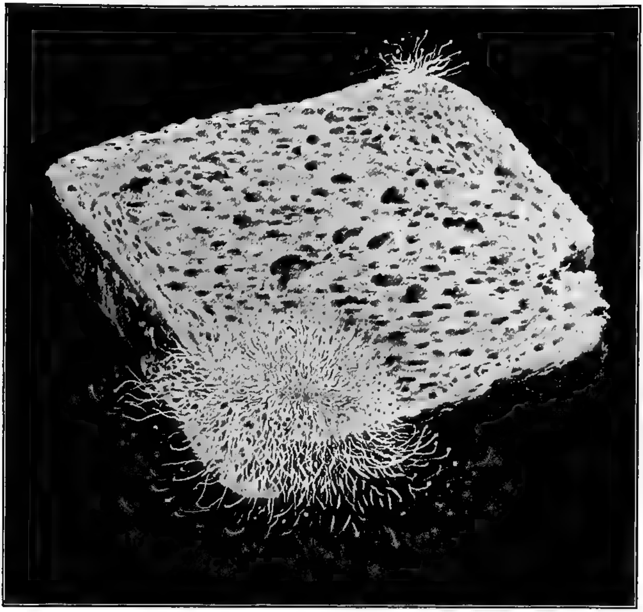


FIG. 2. A piece of bread upon which one of the common molds (*Mucor*) is growing.

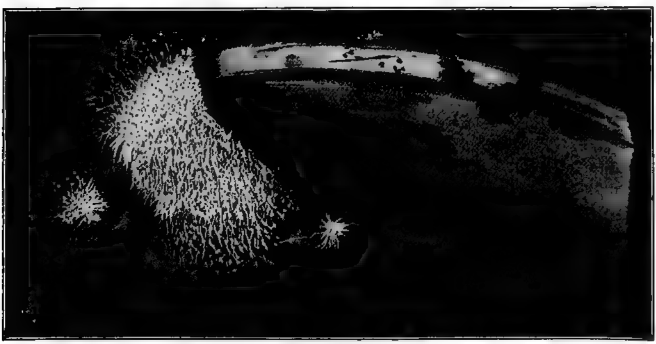


FIG. 3. A common mold, *Mucor*, growing on a bit of banana.

leather, as well as upon a host of other materials. We frequently find upon other foods, especially fruits, two or three kinds of brown molds, and some that even when fruiting remain pure white. Some, again, become pretty nearly black, while still others grow red or pink. One of the very common forms consists of a rather coarse mass of threads, upon which develop numerous black balls containing spores, about the size of a period, while another consists of delicate threads with clusters of white spores looking like snowballs. Each of these different colors indicates a different species of mold. There are scores of species known to botanists, but it is quite unnecessary for the housekeeper to attempt to distinguish them. Pieces of moldy lemon, banana, apple, and bread will be quite sure to show different species of molds.

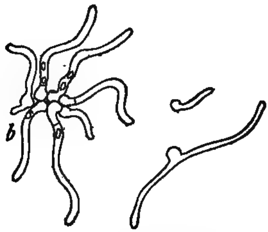


FIG. 4. The sprouting of the spores of *Penicillium*. At *b* there is a cluster of seven spores sprouting to form a colony.

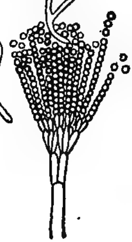


FIG. 6. A cluster of spores of an older colony.

FIG. 5. The growth from two spores two days later than Fig. 4, showing the beginning of the formation of spores, showing method of origin at *a*, *b*, *c*.

Structure of Molds

It requires microscopic study to make out the structure of molds, but it is important to understand this structure in order to be able to explain the conditions under which they grow. If we study a young mold before it has begun to produce its fruit, it is found to consist of a long, highly branching thread (Fig. 5). When it begins to grow all that can be seen is this tangled mass of delicate threads. The threads are so minute, as a rule, that the individual fibers are only just large enough to be seen by the naked eye, and in many cases they are too small to be seen except with a lens. The thread of the blue mold is too small to be seen without a microscope. The threads are practically always of a whitish color, nearly transparent when examined under the microscope, and appear as shown in the several figures. In some species of molds they grow into a very dense, felty, rather tough mass. In other species they form a loose mass of coarser fibers (Fig. 2).

An important point to be remembered is that these threads, by their growth, can penetrate into the depths of the material upon which they are growing. If they are upon the surface of bread, the fine fibers push their way down into the substance of the bread. If they grow upon cheese, the threads force their way into the body of the cheese. When growing upon any soft food material, the mold threads, though visible only on the surface, really extend into the substance for a considerable distance, although they are so small and transparent that we cannot follow them. Of course the readiness with which a mold can grow through food material will depend upon the toughness or firmness of the material. Upon damp leather the thread is not capable of growing underneath the surface so readily as it can upon bread. This thread is known to botanists by the term **mycelium**, and by this term we shall hereafter refer to it. The young mold is a white, loose mass of mycelium, but as it grows older it becomes denser by continued branching of the thread.

Fruit. After a while (usually two or three days' growth) the surface of the mold begins to show some color, — either blue, brown, red, or some other color. The appearance of the color on the surface indicates that the plant is fruiting, i.e. producing **spores** or reproductive bodies. The spores of different species of mold are produced in quite different ways, and botanists classify molds by their methods of forming fruit. It will not be necessary for us to consider more than one or two of them.

In the common blue mold the spores are produced as follows. After the mycelium has grown for some time there arise from its surface tiny threads growing vertically into the air. These threads, after extending for a very short distance, divide into little branches (as shown in Fig. 5, *c*), several branches arising from a single stem. After these branches have grown for a short distance they begin to be divided by slight constrictions, like rings, around them, so that each one of them looks like a string of beads (Fig. 5, *c*). These rings cut deeper and deeper into the branch until finally it is broken up into a string of a dozen or more small round balls (Fig. 6). These little balls (Fig. 6) are the **spores**. When seen under the microscope they appear quite transparent, but when a considerable number of them are seen together they have a bluish tinge. The spore-bearing branches spring up in thousands all over the mold, and after a few days its surface is covered with a mass of thousands of spores, giving to the mold first a slightly blue color and later a darker blue, until the entire surface finally becomes covered with the well-known shade spoken of as blue mold. These spores are extremely light, are very easily blown by the winds and readily float in the air. Every breath of air striking a mass of molds in full fruit will detach some of these minute spores and blow them away.

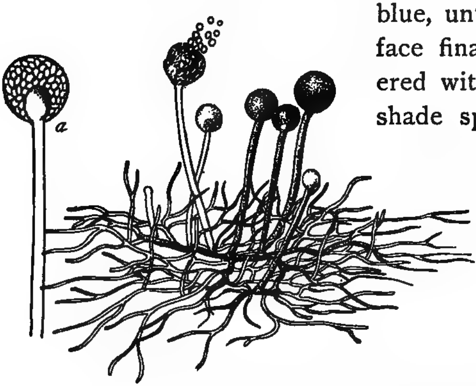


FIG. 7. A colony of *Mucor*, showing the mycelium and the sporangium of the fruit capsules. At *a* is a large sporangium filled with spores.

The species of different molds can easily be distinguished by their different modes of forming spores. A mold common on fruit and bread, called *Mucor* (Fig. 2), produces its spores inside of little sacs borne on long stalks. The mycelium in this mold is coarse and the threads are easily visible, making a loose mass of delicate fibers, and sometimes forming upon bread a fluffy growth an inch thick (Fig. 2). When ready to fruit, threads grow vertically into the air and the end of each thread soon swells into a small rounded knob. This knob continues to grow until it becomes a ball of considerable size, at first white, but finally black, and large enough to be seen with the naked eye (Fig. 7). Inside of this ball the living substance of the plant soon breaks up into hundreds of minute bodies (Fig. 7). These are the spores, and after they have become formed the sacs which hold them (*sporangia*) burst and the little spores are thrown out to be blown about by the wind. These molds are at first soft and white, but later black from the abundance of these spore sacs.

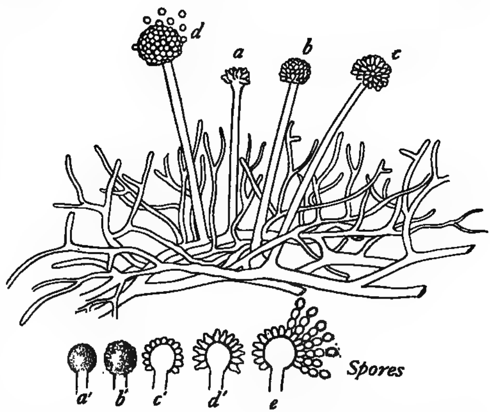


FIG. 8. A colony of *Aspergillus*, showing mycelium and spore clusters. The lower figures show in detail the method of spore formation.

Another very common sort of mold fruits still differently (*Aspergillus*). A fine, threadlike mycelium is produced, as in the other cases, and from it grow the fruiting branches. At the end of each fruiting branch grows a little round ball, from all sides of which project many little knobs (Fig. 8, *a*). These knobs lengthen a little, but soon break up into round spores very much like the branches of blue mold (Fig. 8, *a'*–*e*). The result is that, since they protrude in all directions, there appears on the end of each fruiting branch a little rounded mass, looking very much like a corn ball (Fig. 8, *d*), — a resemblance which is very striking in some species when the spores are white. This species of mold, even after producing its fruit, remains white; but a careful examination shows it to be covered all over with minute white balls just big enough to be seen by the naked eye, but looking very beautiful under the microscope (Fig. 9). Each ball is a mass of scores of spores. Some molds of this last type produce brown spores instead of white.

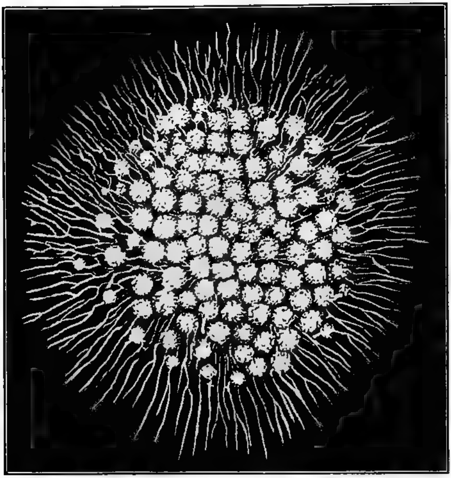


FIG. 9. A colony of *Aspergillus* as shown under the microscope on a black background.

Of the scores of species of molds each has its own method of producing spores. Each is at first a white, threadlike mycelium, but each in time shows spots of color. When the color begins to appear it commonly means that the mold is producing spores. The spores are nearly always so small and light as to be blown easily by the wind, and in this way they are carried to and fro. The air in any household is almost sure to be filled with them in greater or less abundance, as can easily be proved. See experiments 6–8, pp. 272–273. Figs. 14–17 show a variety of common molds, with their methods of forming spores.

FIG. 10. *Mucor*, a common mold.

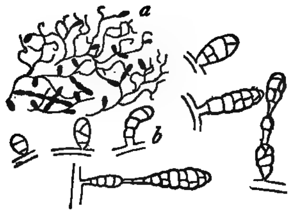


FIG. 11. *Alternaria*, a common mold found upon apples. Mycelium shown at *a*, and enlarged fruiting bodies at *b*.

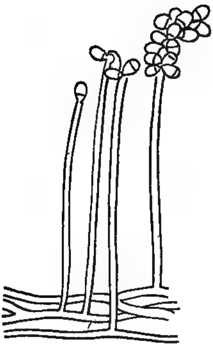


FIG. 13. Fruiting bodies of a mold found upon apple scab, *Cephalothecium*.

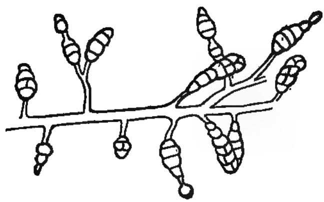


FIG. 12. Fruiting bodies of another species of *Alternaria*.

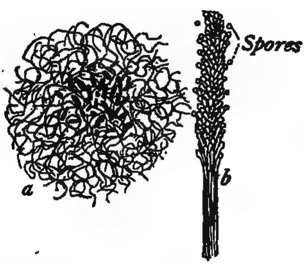


FIG. 14. *Stysanus*, a common mold. *a*, mycelium; *b*, fruiting branch.

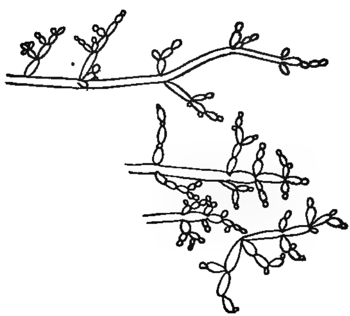
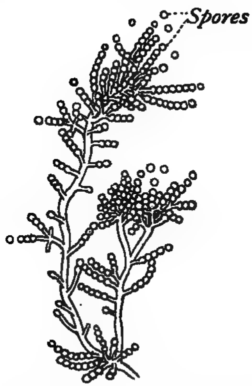
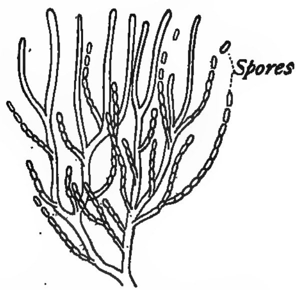


FIG. 15. A common household mold.

Germination of Spores. The function of these spores is to reproduce the plant. If one of them lights upon a proper material having sufficient warmth, moisture, and nourishment for its life, it soon germinates and sends out from itself a little thread (Fig. 5, *a*). This thread feeds upon the material on which it is growing, and continues to extend and branch until within a few hours a new mycelium is produced, thrusting its way into





FIGS. 16 and 17. Two species of molds, *Monilia*, common in cheese.

the food substance and developing into a typical mold. After a day or two the spores are again produced (Fig. 5), and the process is repeated. The air is almost always so well filled with spores of molds that it is quite impossible to leave any food product exposed for any length of time without a number of these living spores falling upon it. If a piece of moist bread, for example, is exposed to the air for a few moments in an ordinary room, and is then covered with a bell glass in such a way as to keep it moist, it will, in the course of a day or two, become covered with molds which have come from the sprouting of spores that

PLATE I

PLATE II

FIG. 18. Plates exposed to the air before and after sweeping, showing the abundance of mold spores in the air. The upper plate was exposed before sweeping, and contains one mold; the lower after sweeping, and contains numerous molds. Each was exposed for one minute.

fall upon it. These spores — including species already described, as well as a variety of others — are almost sure to be floating in the air, and one of the valuable practical lessons for the housewife to learn is that the ordinary air of her house is filled with mold spores which are sure to get upon any food material that is left exposed.

The mold spores, although very light, are slightly heavier than the air, and after floating awhile they sink to the floor, if the air is quiet, where they remain until the air is again disturbed. Sweeping stirs them up, and so does dusting. Fig. 18 represents two plates filled with a jelly upon which molds will readily grow. Plate I was opened to the air for one minute in an ordinary room and then closed. The room was then swept and Plate II was exposed to the air for the same length of time. Both were then set aside until the spores germinated, when the photographs were made. The plate exposed to ordinary air shows only one mold, while that exposed after the room was swept contained large numbers. Dusting a room produces similar results. Even walking through a room, especially with long dresses that sweep the floor, will stir up mold spores. The practical conclusions are thus taught that wiping up dust with a damp cloth is far better than dusting; that carpet sweepers are better than brooms, and vacuum cleaners better yet; and lastly, that no food should be exposed to the air of a recently swept room.

Protection of Food from Molds

The fact that the molding of food starts from spores that drop upon it from the air suggests protecting the food by the simple means of keeping the spores away from it. If we can keep the spores away, no trouble of this sort will arise. For example, jellies made from the juice of fruit, which the housewife puts up for winter use, are excellent material for mold growth, as many a person has discovered after the jellies have been stored away for a time. There is, however, little difficulty in preventing the molding. In making the jelly the material is commonly heated sufficiently to kill the spores present, and if it is afterwards properly covered it will keep well enough.

In protecting jelly from the growth of microörganisms there are several facts to bear in mind. Jelly contains too much sugar and is often too acid to permit the growth of ordinary bacteria. Molds and yeasts, which can grow in it, do not produce spores that are specially resistant to heat; and these organisms, moreover, cannot grow in the absence of oxygen. Several methods have been proposed for preventing spoilage. One of the most popular in former years was to pour a little pure alcohol or some distilled liquor such as brandy over the top of the hardened jelly to kill mold spores that had lodged there and then to seal with a paper cover. For obvious reasons this method is not in wide use in the United States at present.

The most common method now employed in the home to seal tumblers of jelly is to pour a little melted paraffin upon the surface of the jelly. The paraffin should be melted in some dish, like a cup, at the lowest temperature at which it will melt, about 140°. The surface of the jelly may then be covered with a thin layer, which will quickly harden. The object of this method of sealing is not so much to exclude mold spores as to keep out air. The molds, unlike many of the bacteria, are unable to grow unless they have sufficient air. Hence if the seal is good they will not grow on the jelly even though spores are present under the paraffin. This is the reason why tumblers of jelly can be allowed to stand overnight to harden before pouring on the paraffin.

These methods of protecting jelly are not sure, and even after sealing it is necessary to keep the jelly in a dry place to insure its keeping properly. Spores are often left under the paraffin, and it is difficult or impossible to seal so that no mold spore can subsequently enter. Jellies should therefore be stored in *dry* closets to keep them from spoiling. If it should happen that no dry closet is convenient, the air in a damp closet may be partly dried by keeping unslaked lime in bowls on shelves near the jelly. These will absorb the moisture and aid in checking the molding. The lime should be renewed from time to time.

Canned goods will also sometimes mold when the process of canning has not been thorough. This will be considered in a later chapter. We must notice here, however, that when cans of fruit are opened and exposed to the air, mold spores are very likely to drop into them, and if they are then shut up again the contents of the can are almost sure to show a fine crop of molds in a few days. It is almost impossible to open a can of fruit, take out a part of it, and close again, without allowing mold spores to drop into it. This must, of course, be guarded against, and if the whole contents of the can cannot be used at once, the part that remains should be boiled and once more closed as in the original canning. By such heating the spores that may have dropped in while the can was opened are destroyed, and it may be closed and set away safely.

Material which is Liable to Mold

Since molds are fungi, they require to be fed with organic food. Hence they are unable to live, as green plants can, in purely mineral soil. Indeed, they do not grow readily anywhere except upon rich food, and they grow best when feeding upon the same kind of foods that animals require. Whatever contains organic material will support them. They feed readily upon bread, cheese, or meat, and they can also support themselves upon leather or upon woolen or cotton cloth. Some molds grow easily upon damp wood; but although thus capable of living upon almost anything except mineral matter, they grow much more readily on some materials than on others.

Of common foods, cheese is probably the one that molds most readily, partly because it is always more or less moist, and partly because it is quite sure to be inoculated with mold spores. Wheat flour, or any material made from it, like bread or cake, is sure to mold if kept sufficiently moist and warm. A "mustiness" of the flour in the flour barrel is occasionally noticed, and the molding of bread is a common occurrence. All other forms of flour and meal, as well as articles made from them, mold readily enough. Even pickles will occasionally mold; for the intense acid of the vinegar, while it quite prevents the action of the common putrefactive organisms, does not necessarily stop the growth of molds. In short, almost any of the foods which are found in the pantry may, under certain conditions, show mold growth upon their surfaces.

Molding is not confined to food in the pantry, for other substances which contain organic material can furnish proper sustenance for mold growth. Leather, like that of old shoes, if kept in a warm, moist atmosphere, becomes covered with mildew. The same is true of carpets and of woolen or cotton cloth. Such material does not furnish a very luxuriant growth, the effect being commonly called mildew instead of molding. At first sight there seems little similarity between molding and mildew, but the microscope tells us that mildew is really nothing more than the growth of certain species of molds that have not developed very luxuriantly.

Paper is also liable to mold if kept damp, and certain molds are occasionally found in and upon books. Even woodwork will sometimes mold, especially in dark, damp cellars. In short, almost anything in the household which is of vegetable or animal nature may, under proper circumstances, furnish a substratum which can develop a more or less luxuriant crop of these plants.

Results of Mold Growth

The effect of mold growth varies with the species of the mold and also with the material on which it is growing. Sometimes molds are useful, as for example in the ripening of Roquefort cheeses. Upon most of our food products, however, their action is injurious in at least four directions. (1) They make the food unsightly, for few people would be willing to use as food any material upon which a luxuriant growth has made its appearance. (2) They generally injure the taste of the foods, for a peculiar flavor is sure to be imparted to any food product where mold has grown, and after the mold has a luxuriant growth the flavor of the food is so modified that we are usually not willing to eat it. (3) They affect the odor of food. Mold is always sure in time to develop a peculiar smell which we generally speak of as "musty." Mustiness, indeed, is commonly nothing more than the odor that comes from molds. It is due in part to the presence of the microscopic spores which arise from the mold mass, and which, breathed into the nostrils, produce the peculiar effect upon the nose which gives rise to the odor. It is due also in part to gases which arise from the molding material as the result of decomposition. At all events, mustiness is always characteristic of mold growth, and whenever any material or any room smells musty we may be confident that it contains growing molds. We may be sure also that any material capable of molding, if left in such a musty room, will be sure to show signs of molding in a short time. (4) In the end the growth of the molds results in the total ruin of the food, since after a while mold growth produces decomposition, putrefaction, and decay. These later changes are due to the fact that the molds are consuming the material as their own food. While they use the food for their own purposes they are producing chemical changes which result in the production

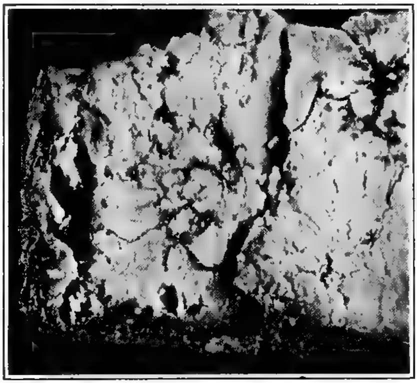


FIG. 19. A bit of Gorgonzola cheese. Dark spot at right on top is mass of mold spores.

of the peculiarly flavored products characteristic of certain forms of decay, rot, or putrefaction.

It must not be understood, however, that putrefaction is produced wholly by the action of molds, even in the materials on which molds are visibly growing; for another class of organisms to be considered later, the bacteria, is more commonly concerned in putrefaction. But molds contribute largely to the development of putrefaction, and in the case of some materials, as fruits, molds are practically the sole cause of this phenomenon.

Molds upon Food not necessarily Unwholesome

The result of these various changes is that almost all foods are soon spoiled if molds are allowed to grow upon them for any considerable time. They rapidly change in flavor, odor, and in appearance, and eventually the putrefaction or decay makes them utterly valueless. If, however, the molding is checked quickly and the food preserved from further molding, or if it is consumed at once, there is no reason why the food should not be utilized, for the mold itself is not particularly unwholesome. We may consume food that has begun to mold without its producing any ill effects upon us, provided that the molding has not extended too far and that we do not eat a great quantity

Fig. 20. A bit of American cheese. No molds are present.

of it. Indeed, Stilton cheese, Gorgonzola (Fig. 19), and Roquefort cheeses owe their delicious flavors to molds. If a large quantity of moldy material is taken at once, it is possible that a slight poisonous effect may be produced; but this practically never occurs in the consumption of moldy food. It is well to remember, therefore, that molds are not unhealthful. It is not always necessary to throw away moldy food; much of it may be used. Moldy cheese is by no means ruined, for the moldy surface may be scraped off and the center will be found as good as ever. Many samples of preserves or jellies which are beginning to mold may be utilized if we simply stop the growth of the mold and preserve the food from further molding. It may be that the mold has developed a slight musty odor and taste, which would, perhaps, injure the value of the food from the standpoint of the palate, but they will not materially have injured its ease of digestion or its value as a food.

It is, however, the desire of the housewife to prevent molding so far as possible, and to check it quickly if it begins, in order that she may thus preserve the valuable foods. To understand the methods by which we may best prevent the growth of mold, or check it if it once begins, we must next consider the conditions most favorable for mold growth.

CHAPTER V

CONDITIONS FAVORING MOLD GROWTH

When a piece of bread or cheese goes bad, it gets moldy; when a bottle of fruit juice spoils, the organisms growing in it (as we shall learn later) are either yeasts or molds; but the spoilage of a can of vegetables, like corn or beans, is almost invariably due to bacteria. Why can molds grow in the first two instances but not in the third? The answer to this question is important, for it shows how to control their growth.

Food Requirements. Like nearly all other kinds of microörganisms, molds require organic matter. As food is always composed of organic matter, they have no trouble in meeting this requirement. Were this the only peculiarity of their food needs, all food would mold; but there are certain other respects in which they prefer quite different food from ordinary bacteria. They like a large amount of sugar. Most bacteria can use sugar; but if a fluid contains as much as two per cent of sugar the growth of ordinary bacteria is decidedly inhibited. Quite the contrary with molds. They grow well even with larger percentages of sugar. One reason for this difference is that when a microorganism grows in the presence of sugar, this substance is converted into acids; and it requires only a small amount of acid to prevent the growth of the ordinary decomposition bacteria. Molds, however, grow best if there is a little acid present, and they tolerate a considerable amount of it.

From this it is easy to understand why certain kinds of food mold while certain others spoil from the growth of bacteria. If a food contains much sugar, like jelly, or much acid, like lemons, bacteria cannot grow in it; while molds, if neither the sugar content nor the acid is too high, are not inhibited. If, on the other hand, a moist food is low in sugar and acid, ordinary decay bacteria are likely to grow so rapidly in it that the molds cannot get started.

This is not the whole story, however. Yeasts, as well as molds, like much sugar and tolerate considerable acid. We must look further into the peculiarities of these organisms before we can learn why some foods spoil from the action of molds and others from that of yeasts.

Moisture. A factor of primary importance in the growth of all microörganisms is water. A vigorous growth of molds requires an abundance of moisture, and in dry material they will not grow at all. There is, however, a very distinct difference in this respect between molds and either bacteria or yeasts. Bacteria and yeasts ordinarily prefer liquids to solids, and grow only in solids that have a high percentage of moisture. If, therefore, the moisture content of any material is quite low, like that of flour stored in a damp place, molds can grow but neither yeasts nor bacteria. This particular illustration is interesting: flour is not acid and contains practically no sugar, but molds will grow in it because its low moisture content prevents the growth of bacteria or yeasts.

It must be emphasized, however, that some moisture is necessary even for molds. Flour that is stored in a dry place can be kept indefinitely without molding. In fighting molds, therefore, one line of attack is to exclude all moisture.

Water for their growth may be supplied by the air in which the food is kept, or by the food itself.

1. The air is the source of the water when flour, which naturally does not contain enough moisture to support even molds, becomes covered with a growth of these organisms. Flour is not the only material thus affected. A large variety of materials in the household, ordinarily free from molding, may show signs of **mildew** during a damp season. The mustiness of a closed room is due to the presence of molds, and is always an indication of dampness, for dry rooms neither show signs of mold nor do they smell musty.

2. Some materials contain within themselves sufficient water to produce a vigorous development of molds. Fruits, for example, are so full of moisture that they are equally good food for molds whether kept in a dry or a moist place. *If the mold once gets a start* (which, by the way, is very difficult in a dry atmosphere), the fruit itself furnishes all necessary water. Jellies and other similar preserves also contain sufficient moisture.

From this it follows that food capable of being thoroughly dried may be protected absolutely from molding if stored in a dry place. It also follows that any condition which favors moisture, such as darkness, stagnation of the air, proximity to the soil (as in cellars), is likely to permit the growth of molds. Under such conditions not only food, but also leather-covered books, shoes, pocketbooks, and even carpets or clothes may become covered with mildew. In damp weather no animal or vegetable material is beyond the possibility of molding; but if it is placed in a dry atmosphere the growth of molds may be entirely prevented.

Aëration. We have just seen that molding is stimulated by stagnation of the air. This is not because molds do not like air, but because air currents cause drying and deprive them of the necessary moisture. Molds need oxygen, just as we do, and hence require some air; thus molding almost always begins on the surface of any substance attacked.

In this matter of aëration molds are quite different from either bacteria or yeasts. Bacteria and yeasts, like fishes and other aquatic animals, can live on the oxygen dissolved in the water around them; some bacteria can even grow in the entire absence of free oxygen. Molds, on the other hand, can never grow in its entire absence; and although they can probably use dissolved oxygen to some extent, they apparently prefer to obtain it from the air. Sometimes one can actually drown a mold by keeping it beneath the surface of a liquid in which it could grow well if it were allowed to float on the surface.

These facts show why molds do not cause the spoilage of canned vegetables. A can of vegetables is ordinarily sealed too tightly to allow the entrance of air; so some kinds of bacteria may grow, but molds cannot. Furthermore, if air is able to get in, the bacteria can grow so well in such material that they prevent mold growth. In canned fruits or fruit juice molds cannot grow unless air gets in; but if the seal is not tight they can grow, because the abundance of sugar and acid in such material prevents the growth of bacteria which would keep down mold growth if they could flourish. In jellies molds are ordinarily the only microörganisms capable of growing, because of the high acid content and large amount of sugar. Hence in making jelly one does not have to be careful to keep out microörganisms but merely has to seal it in such a way as to keep out air and thus to prevent mold growth.

Temperature. Molds, like bacteria and yeasts, require a moderately warm temperature for vigorous growth. At a temperature slightly below freezing they will not grow at all, and at a few degrees above freezing their growth is very slight. Some species of molds, however, grow readily enough at 40°, growing better at this than at a warmer temperature. Hence it follows that the temperature of an ice chest will not wholly prevent molding. The still lower temperatures of mechanical refrigerators are more efficient, while those of cold storage (slightly below freezing) prevent mold growth almost entirely. Most common molds, however, either fail to grow at an ice-chest temperature or grow very slowly. As the temperature increases, however, the growth becomes more vigorous, and at temperatures varying from 70° to 100° the growth of these plants is stimulated to their highest activity. A practical result from these facts is that any material which can be kept sufficiently cool will fail to show signs of mold, even though tightly closed in an atmosphere saturated with moisture and abundantly sown with mold spores.

Killing by Heat. In considering the relation of temperature to molds a fact of great importance is that high heat will always destroy molds and their spores. Boiling ordinarily kills spores as well as mycelium. Hence any food which has begun to mold, and which is of a character to allow heating, may be protected from the further growth of the mold by boiling. This method of treatment will be possible for many preserves, canned foods, or any food that has been previously cooked. It may be applied to preserves, sauces, jellies, mince-meat, and even pickles. It would not be practicable, however, with foods whose flavor is destroyed by cooking. Fresh fruit which has begun to mold cannot be treated in this way without destroying the original fruit flavor and giving in its place the taste of fruit preserves or sauce. It is always necessary to remember that after such heating the food is liable again to receive more mold spores from the air and may therefore later show another growth of molds.

Practical Summary

From all these facts we may reach practical suggestions as to the methods of avoiding the growth of molds. (1) The most important of all is that food should, so far as possible, be kept tolerably dry. If it is of a nature that will stand drying, it may be protected indefinitely if once dried and not allowed subsequently to become damp. Indeed, in a pantry or a cellar, molding commonly means excessive dampness. (2) Foods are more free from mold if exposed as much as practicable to light and air rather than if kept stored in dark boxes. It is of course necessary to keep some kinds of food in closed boxes in order to prevent them from becoming too dry, but it is useful to remove such food occasionally, to scald the container, and to expose it to the air and sunlight in order to prevent any great accumulation of mold spores. (3) The growth of molds may be almost completely stopped by lowering the temperature, and therefore foods that are particularly liable to mold may be prevented from molding for a long time if kept in a refrigerator.

CHAPTER VI

THE DECAY OF FRUIT; USEFUL MOLDS; MOLD DISEASES

Of all food materials commonly found in the household none are so much injured by molds as fruits. Most *pears*, *plums*, and *peaches* decay rapidly; *apples*, *oranges*, and *bananas* keep somewhat longer, but it is a universal experience that none of our ordinary fruits can be kept for any considerable length of time without decaying (Fig. 21). Winter apples, with their solid flesh and their tough, smooth skin, can be kept for many months without rotting, and the thick skins of oranges and lemons protect them a long time. But thin-skinned fruits, like cherries or berries, can be kept only a comparatively few days.

FIG. 21. An apple beginning to decay under the action of certain species of molds.

The decay of fruit is by no means always alike, and it is produced by a variety of causes. If one simply examines decaying apples, pears, lemons, and bananas, the difference in the character of the decay is quite evident both to the eye and to the smell. *Bitter rot, black rot*, and *brown rot* are three types produced by three different organisms. It is not within the scope of our study to describe the different kinds of decay which appear in common fruit. The causes may be numerous, but in the majority of the examples of decayed fruit the active agency,

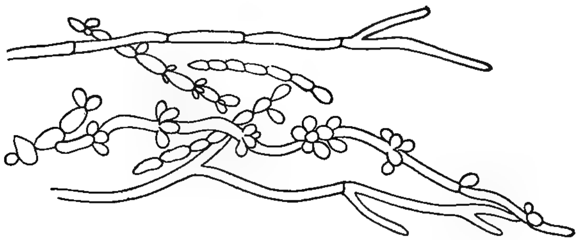


FIG. 22. *Monilia*, a common species of mold causing fruit decay.

at the start at least, is the growth of molds. In later stages of the decay bacteria may be concerned, but it is always molds that begin the process. There are a number of species of molds intimately associated with the decay of fruits. The common blue mold (Fig. 7) is one of the most widely distributed, but there are several others (Figs. 22, 23, 24).

Method of Infection and Distribution

To understand the decay of fruit we must first bear in mind that mold spores are constantly floating in the air, and that they may also be carried easily upon the feet of insects that chance to light upon a bit of spore-bearing mold. By some such agency mold spores are quite sure to find their way to the skin of any piece of fruit. But after they fall upon the fruit they will not grow unless the conditions are right. If the skin is whole and smooth and dry, they do not readily germinate. Commonly they start at some small crack in the skin through which the thread sprouting from the spore can thrust itself into the softer parts within. Hence whole-skinned fruits are easier to keep than those with bruises. If the spores find sufficient moisture on the skin, and a convenient crack, they soon send a tiny mycelium thread into the fruit. This grows luxuriantly, branching profusely, and presently pushes its way in every direction through the soft pulp of the fruit. The fruit begins to soften and decay. The rotting is caused by the growth of the mold mycelium in the flesh, the visible decaying spots being simply the external evidence of the mold growing within.

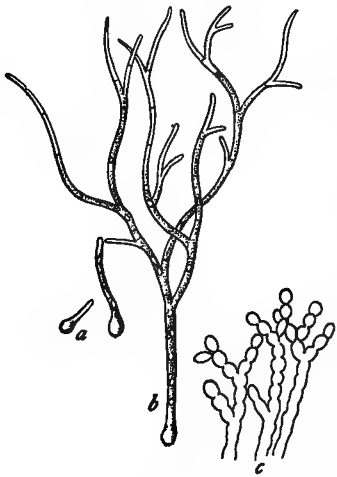


FIG. 23. *Monilia*, showing the formation of spores at *c* and the sprouting of spores at *a* and *b*.

After a time the mold begins to form its spores. To do this it generally breaks through the skin so that the spores may be formed in the air. These spores can easily be seen in a well-decayed apple (Fig. 25). The spores thus produced are then scattered into the air from the broken skin of the fruit. They are carried either by air currents or by insects, or, if the pieces of fruit are in direct contact with each other, as is almost always the case when packed, one piece of fruit will directly infect the next and thus start a new center of decay. In this way decay which begins with a single piece of fruit is

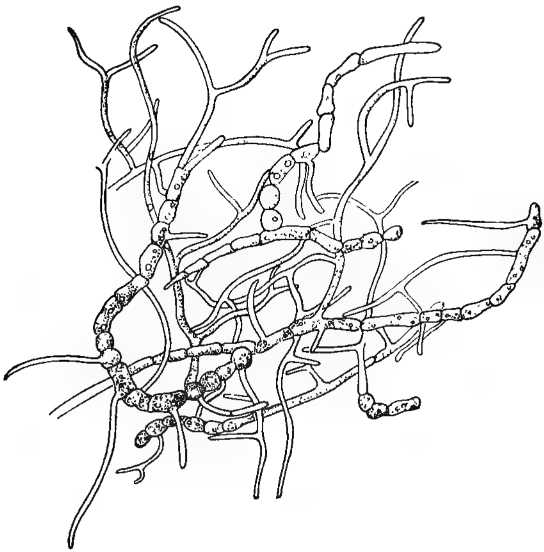


FIG. 24. Another species of *Monilia* taken from a decaying apple, showing formation of spores.

sure in a short space of time to extend to the neighboring pieces. From a single decaying apple, infection may spread from apple to apple until a whole barrel speedily becomes decayed and ruined. It is an example of direct contagion.

A practical suggestion arising from these facts is the wisdom of removing from the vicinity of sound fruits all that show signs of decay, since decaying fruit will surely be shedding spores which will infect the sound fruit. Such fruit, therefore, should not be allowed to remain in a pantry with other fruit, nor in a cellar. Nor should it be allowed to accumulate in heaps near the home, for insects and air currents are sure to distribute the spores. The removal of all decaying fruit, or its total destruction, therefore, is a necessary safeguard to protect the sound fruit that remains.

Protection of Fruit from Decay

There is no thoroughly successful remedy for the decay of fruit. It is true that fruit may be preserved absolutely from such decay; but this can only be done by the process of canning, or by some other method of preserving which involves operations totally changing the character of the fruit. These we shall consider in a later chapter. It is not possible by any known means to preserve fruit indefinitely from the attack of molds and at the same time to retain its original, natural, fresh condition. Even the hardiest and toughest of fruits will, in the course of months, begin to

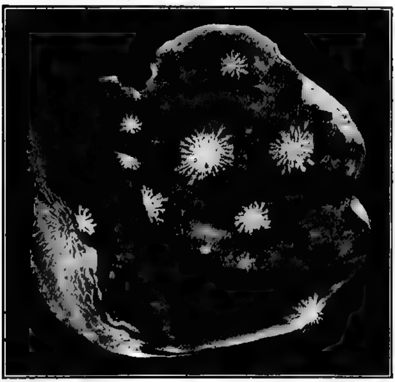


FIG. 25. A small bit of an apple under a microscope, showing the molds breaking through the skin to produce spores, and showing the mycelium running through the substance of the apple.

show signs of decay, though some kinds may be preserved much longer than others. But although it is not possible to prevent absolutely the growth of molds, it is quite possible to delay it very materially if proper care is taken of the fruit. Fruit which would ordinarily keep only a few weeks may, if properly treated, be kept through the winter until the spring. Different fruits vary much in their ease of preservation. Peaches, cherries, and berries can hardly be preserved at all; pears only a little longer. Grapes can be kept a few weeks or longer if special care is taken. Apples, oranges, and lemons can be kept many weeks or even months.

Moisture. We have learned that some moisture is a necessary condition of mold growth. But in considering the application of this fact to the decaying of fruit we must remember that the interior of fresh fruit itself is always moist, containing, indeed, quite sufficient water for the development of the molds, provided they can once get through the skin. Hence the decay of fruit goes on about equally well in moist and in dry air, *provided the molds once get a start*, and it cannot be prevented by keeping the fruit dry.

But the moisture which accumulates upon the skin of the fruit is a most important factor in its tendency to decay. The mold spores are quite incapable of germinating unless they are moistened, and any fruit, the skin of which is kept perfectly dry, is very largely protected from decay, because the spores get no opportunity for germinating. If the skin of the fruit can be kept clean as well as dry, the rotting may be delayed for a very long time.

This is no easy matter, for there are almost sure to be some depressions in the skin, such as cracks or dents, and in these moisture is sure to accumulate. The depressions around the stem or the eye of an apple serve the same end, and, in damp air, water is so likely to accumulate here that molding starts readily. Once germinated the threads quickly force their way into the apple around the stem and find plenty of moisture in the flesh of the fruit. Hence any devices which tend to keep the skin of the fruit dry are at the same time devices for checking the first steps of decay. Fruit whose skin is wiped frequently with a dry cloth will keep better than fruit that is not thus wiped. This question of moisture explains also why it is that fruits begin to decay first at points where two pieces come in contact with each other, since here there is a much better opportunity for moisture to condense. We also learn why fruit which has been cooled to a very low temperature — as in cold storage — and subsequently warmed, may decay more quickly than fruit which has not been cooled. The cold skin of the fruit taken from cold storage causes a slight condensation of water, and then when subsequently warmed this water furnishes a favorable starting point for the germination of mold spores. This explains also why covering with sawdust or charcoal is of great value in checking the decay of fruit. If packed in sawdust, fruit may be preserved a long time, because the sawdust absorbs moisture and prevents the accumulation of water upon the fruit skin. Charcoal serves the same purpose. For some fruits, like pears, oat chaff or rye chaff serves better than sawdust.

This absorption of moisture explains also the efficacy of one of the best means known for preventing the decay of fruits. Experience in past years has shown that the wrapping of fruits with paper is a more efficient means of protecting them from the ordinary rot than almost any device that has ever been adopted. There may be two reasons for this. Wrapping the fruit with paper protects it to a considerable extent from mold spores, which would drop upon the skin from the air if it were not thus protected. But this is doubtless not the chief reason for the value of the paper wrapper, since the fruit is almost sure to be infected with the mold spores while still on the trees, and certainly before it can be wrapped in the paper. The paper used is of a soft, porous nature, and, when properly wrapped around the fruit, absorbs quickly any moisture that may be upon the skin, and prevents moisture from further condensation.

Clean Skin. The facts mentioned also clearly explain the value of a smooth skin. Since decay always starts from spores that lodge on the skin, any method of preventing their lodging or of removing them will protect the fruit; hence the wiping of fruit with a clean cloth will be useful in protecting it from decay. Wiping cannot, indeed, wholly remove the spores, but it aids materially. Moreover, if the wiping is done with a dry cloth, it will also remove the moisture, a matter of no small importance. Fruit dealers, who have learned by experience how to handle fruit, understand well that a frequent wiping of fruit till it is dry and clean is a necessity for its best preservation. It is sometimes surprising to see in what fine condition some dealers can keep fruit far into the spring months by the simple devices of low temperature and clean, dry skins.

Temperature. We have already noticed how effectively low temperatures check the growth of molds, and this applies of course to their growth in fruit as well as elsewhere. If fruits could be actually frozen, the decay could be indefinitely prevented. But this is not possible with common fruit, since the freezing injures its character. All that can be done, therefore, is to cool the fruit to as near the freezing point as possible without actually freezing it. If the temperature is lowered until the fruit is near to the freezing point, the growth of the molds may be so delayed as effectually to prevent the fruit from decaying for very many months. This can be done readily in the modern cold-storage plant, and fruit growers have now learned by practical experience that cold storage furnishes a means of keeping fruit for the spring market. To be sure the expense of such storage is a considerable item, but the extra price that may be received in the spring may more than make it good. If one has not the opportunity for cold storage, it is best to keep fruit in cool cellars where the temperature does not go down to freezing and is tolerably constant. The lower the temperature (above freezing) the better. The temperatures of cool cellars are not, however, low enough to prevent mold growth wholly. They will not prevent the final decay of the fruit, but they are very useful in delaying it. When fruits are removed from such cellars it must be remembered that they are cold and will condense water rapidly on their surfaces. They should be wiped dry after being in the warm air a few hours, or they will decay quickly.

Rotting of Fruit due to Diseases of the Fruit Tree

In addition to the rotting of fruit due to the growth of common molds, it is important to know that many diseases are caused by certain microörganisms that attack the plants upon which they are growing, or attack the fruits themselves while still growing upon the fruit trees. These sometimes produce various kinds of rots and decay in the fruit even before it is plucked (Fig. 26, 27). In some cases the fruit may appear to be perfectly sound when picked from the tree, but it is really already infected with molds which cause it later to show signs of decay (Fig. 21). Nearly all of the diseases in question are caused by molds somewhat similar to those we have already considered, but of different species. Botanists know a large number of species of molds which grow upon different fruit trees, producing diseases of the tree and accompanied by decay of the fruit. So far as concerns affairs of the household these imperfections are quite beyond the reach of efficient remedies. If the fruit which we buy at the market and

Fig. 26. Peaches turned into a hard mass (mummified) by the action of fungi.

bring to our houses is already infected with the molds in question, nothing that we can do will protect it from their subsequent growth and consequent decay. The only alleviating remedy is, as mentioned in other cases, to keep the fruit cool, because none of these microörganisms grow readily while in low temperatures. Dryness is of no value, since the molds are already within the fruit, where there is moisture enough.

FIG. 27. Peaches decaying on the tree.

This cause of the decay of fruit is, however, of no very great significance to the ordinary household, because in a great majority of cases the fruits infested with these troubles will show some signs of decay before they reach the market. The loss comes upon the fruit grower, upon the person who buys the fruit for storing, or upon the dealer; rarely will the decay thus produced be delayed sufficiently for the fruit to be marketed, sold, and carried away by the customers. The consumer would not distinguish this from the more common types of decay. For this reason this type of fruit disease, while of great significance to the farmer and to the one who handles fruits, is of no very great importance in the ordinary household and need not here be further considered.

Utility of Molds

We never look upon molds as of any particular utility. Nevertheless, when we study their relations in nature we find that they are of the utmost importance. In the processes which are going on in nature the molds form a very important link, aiding in furnishing different kinds of living beings with food. The woody part of trees contains a large amount of material which cannot be used as food by either plants or animals. Were it not for some agent which brings this material into condition for subsequent use by plants and animals, much of the food material of the world would in time become stored away in the form of wood, and the world would materially suffer as the result. But the tree trunk does not remain a hard, solid mass very long after it has fallen to the ground. It slowly softens and decays, until eventually it assumes a condition in which it can again be used for food by various animals and plants. Insects, for example, feed upon the decaying wood until, in time, the tree trunk is all consumed. In this process a group of fungi similar to molds plays an important part, for it is a mold-like mycelium growing through the hard surface of the wood that begins the softening necessary to make its utilization possible. With this we are not particularly concerned, for the household is not usually concerned in the decay of wood. Wood in the household may occasionally decay, but it is such a rare circumstance that the housewife pays little attention to it.

In recent years it has been learned that molds are valuable commercially in the production of certain chemicals which have industrial uses. A few food products, moreover, are benefited by the development of molds. As already noticed, the peculiar flavor of certain cheeses is due to the growth of molds. *Roquefort* cheese, by a special device of the manufacturer, is caused to mold. When cut open this cheese shows green spots extending through its substance, and these little green masses are simply the spores of molds which have developed in the cheese during its ripening. *Stilton* cheese, a variety made in England, and *Gorgonzola* are also ripened by molds. *Camembert* cheese, a type of soft cheese very popular in Europe and beginning to obtain a considerable market in the United States, is always covered with molds which have developed during the ripening of the cheese, and have contributed to its flavor. *Brie* cheese is another type whose flavors are due to molds, and there are several others less well known.

Diseases of Animals produced by Molds

Some species of molds may live a parasitic life. Many species live as parasites upon plants, sending their mycelium into the leaves or stems of the plants, and producing thus a variety of diseases. With these we are not concerned in this work. A few molds can live a parasitic life upon animals, and there are consequently a few animal diseases produced by molds. The mold diseases of mankind comprise two or three common skin diseases, which sometimes become quite troublesome.

The most common of these mold diseases in man is called **ringworm**, an affection of the skin which produces open sores. These sores spread in all directions from a central starting point, and as they spread they heal in the center, though continuing to spread at the edge, thus producing a ringlike growth that has given origin to the

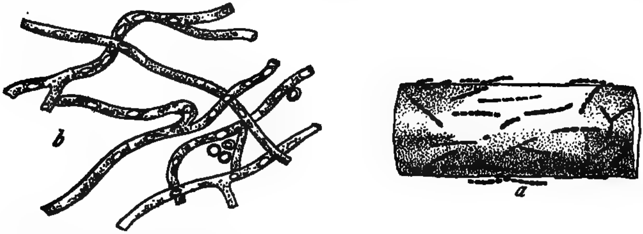


FIG. 28. A mold (*Trichophyton*) which produces ringworm. At *a* is a bit of hair with the mold spores on the outside, and at *b* a figure of the mold itself highly magnified.

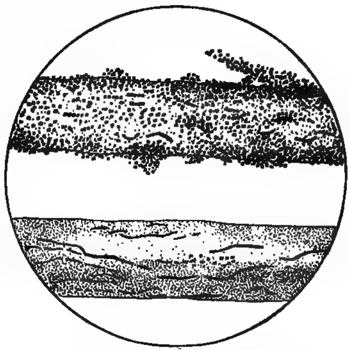


FIG. 29. Two pieces of hair from the scalp infested with a mold (*Microsporon*) producing ringworm. The upper figure shows the masses of spores attached to the outside of the hair; the lower figure shows the mold thread lying beneath the spores.

name. The affection is a troublesome one to heal, especially when it gets into the scalp; it may produce bald spots, but is never very serious. Two or three types of this disease have been found to be produced by two or three kinds of molds. Fig. 28 shows one of the common species that is the cause of ringworm. At *a* is shown a bit of hair with the mold fungus and mold spores growing upon it, and at *b* the fungus more highly magnified. Of the several species of molds that produce this trouble some are more liable to grow upon the hair and others upon the smooth skin, the latter proving less troublesome to heal. A second skin disease is **favus**, sometimes difficult to distinguish from ringworm, although it is produced by a different species of mold, shown in Fig. 30.

In the case of both of these diseases the affection is spread by means of mold spores discharged through the skin. They are liable to be carried from person to person by the use of combs or towels, or even cloths and sponges used in washing or bathing the skin. If, therefore, there is an example of ringworm in a family, it is imperative, in order to prevent the spread of the disease from one to another, that the person suffering from the attack should have his own combs, his own towels, his own sponges, and even his own soap for washing. By this means the disease can usually be confined to the person in whom it originally appears. The cure of such diseases must be left to a physician.

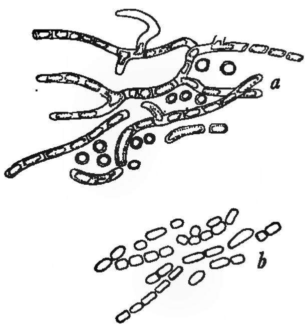


FIG. 30. A mold (*Achorion*) producing a second type of skin disease known as *favus*. At *a* the mycelium is shown, at *b* the spores as found on hair.

MOLD-INFECTED ROOMS

Sometimes a room, like a pantry, may become badly infested with molds, so that all sorts of food become rapidly infected by them. This is an indication that the room is filled with mold spores in such numbers that they drop into everything exposed. The remedy for such condition is to get rid of the spores. The room should be vigorously swept and dusted, a windy day being chosen, and all windows and doors should be left wide open to blow out the dust. After a thorough airing the room should be closed again and left undisturbed until the remaining dust settles; then the floor, shelves, window sills, etc. should be wiped with a damp cloth. This will usually remove the spores, and food will subsequently be less liable to mold. A far better method is to use a vacuum cleaner, which removes the mold spores without scattering them in the air.

SECTION III — YEASTS

CHAPTER VII

YEASTS AND THEIR DISTRIBUTION

Fermentation

Yeasts are the most important among the natural agents which bring about **fermentation.** This term has several meanings to scientists, but as the word is commonly used it refers to a process by which alcoholic liquors are produced from sugary solutions. Fermentation is therefore the basis of the various alcoholic beverages known to civilized as well as to uncivilized races. Fermentation is also the foundation of another phenomenon apparently quite different in its character; for the raising of bread by yeast is just as truly a fermentation as is the manufacture of beer.

The essential phenomena of fermentation are the destruction of sugar and the production from it of two other substances. The sugar is originally a solid, although it is very easily dissolved in water. It is a somewhat complex body, but by the action of yeasts it is easily broken to pieces to form two simpler ones. One of these, **alcohol,** is a liquid and remains in solution; the other, **carbon dioxide,** is a gas and usually passes off from the solution in the form of bubbles (Fig. 31). It is this production of alcohol and carbon dioxide that is the foundation of all fermentative phenomena. Chemists represent the action that takes place as follows.

$$\underset{\text{(sugar)}}{C_6H_{12}O_6} = \underset{\text{(alcohol)}}{2\,C_2H_6O} + \underset{\text{(carbon dioxide)}}{2\,CO_2}$$

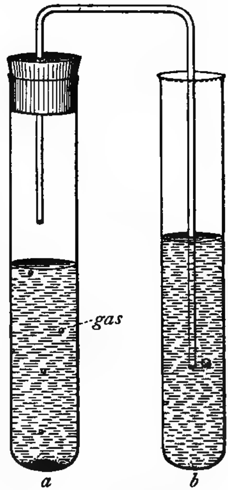


FIG. 31. Fermenting solution of molasses, showing at *a* the growing yeast with the bubbles of carbon dioxide arising, and also the arrangement for conducting the gas underneath limewater at *b*, for the purpose of determining the nature of the gas.

The phenomenon of alcoholic fermentation has been known for many centuries, traces of such knowledge being found as far back as we have any recorded history. Back in the earliest historical days mankind was familiar with certain fermented drinks. At the present time we find that the phenomena of fermentation are known by nearly all races of men, and there is hardly a tribe of savages without its own kind of fermented drink. These intoxicating beverages are obtained from a variety of different materials by different races. The juice of grapes has long been used for the purpose, but various other fruits serve equally well. The juice of the palm tree is used by some races, and sweet juices of various other plants are also used. In all cases the material must contain sugar, or something that can be converted into sugar; for it is always sugar which undergoes the fermentation, no other source of alcohol being practical for producing intoxicating beverages. In the process of bread making, too, fermentation has been known almost as long; for we read in literature of leavened and unleavened bread at least three thousand years ago.

Although fermentation was thus long known, its cause remained a mystery until the nineteenth century. The type of fermentation which we are considering is in all cases produced by essentially the same agency, a group of plants called **yeasts.** It is not always the same species of yeast, for the group includes quite a large number of different species. The commercial product is simply one kind that has been cultivated for commercial purposes; but there are many others in nature not under cultivation which may conveniently be called **wild yeasts.** All of the kinds are, however, very similar in appearance, have the same general characters, and are closely related to each other.

The yeast plant was first seen two centuries ago by a Dutch microscopist, who found fermented liquors filled with minute bodies, the significance of which he did not understand; nor was it known that they cause fermentation until about the third decade of the nineteenth century. At that time it was quite conclusively demonstrated that these minute bodies were living organisms, capable of feeding, growing, and multiplying, and having a very close relation to the phenomena of fermentation. It was soon shown also that it was their *growth* that produced the fermentation, since this phenomenon would not occur unless these organisms were not only present but also growing and multiplying. In our study we must first learn the nature of the yeast plant.

What are Yeasts

Yeast plants are always microscopic, no species being large enough to be seen with the naked eye. When these tiny plants are massed together, as in a yeast cake, the mass may form a bulk large enough to be seen. We can see a yeast cake, but the individual yeast plant is not more than $\frac{1}{2800}$ of an inch in diameter, and this is far below the power of the unaided vision. By the microscope alone we learn that the yeast mass is made up of millions of minute bodies, each of which is an individual yeast plant.

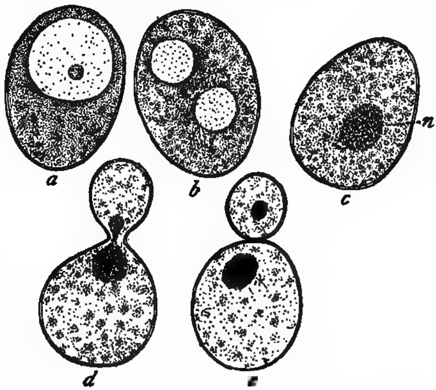


Fig. 32. Common yeast very highly magnified. Figs. *a* and *b* show vacuoles; *c* shows a nucleus *n* inside of the yeast cell; *d* shows a budding cell with the nucleus dividing; *e* shows the cell divided, the new cell containing a bit of the old nucleus.

The yeast plants are much simpler than the molds. If a bit of a yeast cake be mixed with a little water and examined under the microscope, there will be found what is shown in Fig. 32. There will be seen large numbers of minute oval bodies, sometimes very nearly spherical or sometimes considerably longer than broad. They are quite colorless and nearly transparent, as seen under the microscope, but whitish when seen in bulk. They have a uniform, smooth outline, but inside of them may commonly be seen some smaller bodies. There is usually a somewhat rounded clear spot, as shown in Fig. 32, *a*, although in many cases instead of one we find two, three, or four smaller ones (Fig. 32, *b*). These apparently represent only little drops of an oily liquid and have, so far as we know, nothing very particular to do with the life of the yeast plant. These drops are called **vacuoles.** No further bodies can be seen in the yeast cell by ordinary methods of study, although special microscopic devices show that there are other bodies inside (Fig. 32, *c*). These other smaller bodies need not, however, concern us. The yeast cell thus described is quite unlike ordinary plants, showing less resemblance to them than molds. But though they bear no likeness to what we commonly call plants, biologists are unanimous in their opinion that they are to be classed with the molds as colorless plants and, hence, as **fungi.**

Yeast exists in three somewhat different states: (1) the resting state; (2) the growing state; (3) the spore-bearing state. The yeast in an ordinary yeast cake already described is in the resting state. Such yeast appears as in Fig. 32, *a*, each plant being a single oval body or cell. It is alive but is not actively growing.

The Growing State. When a little resting yeast is placed in a solution which contains proper material for food it begins at once to consume the food and grow. As it grows it multiplies by a method known as **budding.** Upon the sides of the yeast plants appear small buds (Fig. 33, *a*). Each bud at first appears as a little swelling on the side of the larger yeast cell. This little bud increases in size until finally it may be as large as the original plant (Fig. 33, *c*). Usually by this time, if the growth is vigorous, there may have appeared a second bud. The latter sometimes arises from the side of the first cell and sometimes from the side of the first bud, giving an appearance such as is shown at Fig. 33, *c*. This budding continues, the little buds appearing one after the other, until there are produced irregular-shaped groups like those shown at Fig. 33, *d*. For a considerable time the cells in these groups remain attached to each other, so that a little of the sediment from a fermenting liquid will appear under the microscope as shown in Fig. 33, *d*. After a while, however, the different cells drop apart and may go into a resting stage, each cell remaining by itself. These cells are capable of growth and development, either immediately or subsequently, when again placed in a solution which furnishes them food. This method of multiplication, which is distinctly characteristic of yeasts and separates them sharply from bacteria, the next group of plants to be studied, is known as budding. The yeast plants are therefore sometimes called the **budding fungi.**

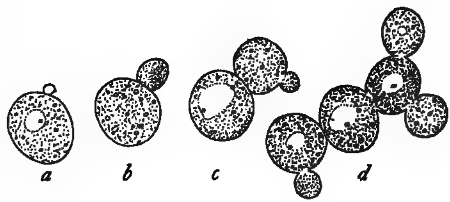


FIG. 33. Growing yeast cells, showing method of budding and forming groups of cells.

The Spore-bearing State. Under some conditions yeast plants produce a different kind of reproductive body known as spores. If a lot of yeast is placed where it has moisture but insufficient food, it does not grow by the normal method of budding, but its contents break up into several parts. In Fig. 34 is shown one of these yeast cells which has been growing on a porcelain plate without sufficient nourishment, and it will be seen that four small bodies have formed inside of the cell. These bodies are **spores** and are capable of resisting for a long time a variety of adverse conditions, such as drying, heating, etc., without being injured. When the yeast cell breaks, the little spores burst forth ready to be distributed by the winds or by any other convenient means.

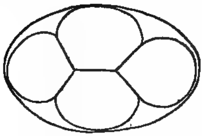


FIG. 34. A yeast cell containing four spores.

Not all species of yeasts are yet known to produce spores of this kind, although it is a characteristic possessed by a large number (Fig. 35). Botanists divide yeasts into two divisions in accordance with their power of producing such spores. The genus *Saccharomyces* includes yeasts which produce spores, while the genus *Torula* includes those that do not. The number of spores formed in a single yeast cell is not always the same, although commonly three or four. It may not always be the same for the same species of yeast.

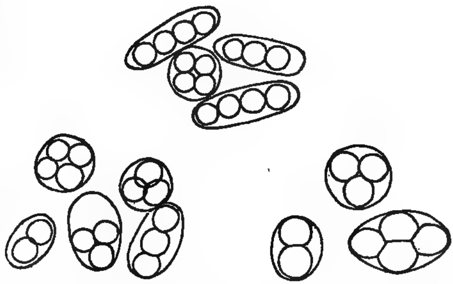


FIG. 35. Three species of yeast each containing spores.

Where Yeasts are found

From the fact that sugar solutions will always ferment, it will readily be understood that yeasts have a wide distribution, even though they do not grow luxuriantly except in sugar solutions. The spores are excessively minute and are capable of being thoroughly dried without injury, in which condition they will remain alive for months. These spores are easily blown by the winds and distributed far and wide. Even the bodies of the yeast cells in their resting stage, before they have produced spores, may be dried, and for considerable time suffer no injury. These dry yeast cells will keep for weeks and sometimes for months without losing their power of growth. The commercial dried yeast cake, which will be referred to presently, contains not yeast spores but simply dried yeast cells. These are still alive and remain for a long time capable of growing if placed in proper conditions of food and moisture. Such dried yeast cells are very light and easily distributed by currents of air. In such dried form yeast is distributed in dust by the winds, and may be found almost universally present over the surface of the earth, except in the middle of oceans and deserts. Elsewhere the air, the soil, and the water are practically sure to contain yeast in greater or less abundance.

Such yeast plants, or yeast spores, blowing around in the air have sometimes been called **wild yeast**, a name quite convenient for distinguishing plants which are indiscriminately scattered in the air from those which we cultivate in great masses for purposes of brewing, bread making, etc.

Spontaneous Fermentation. These wild yeasts are so common in the air that they are sure to be present in most localities, and they fully explain certain phenomena of fermentation that seem at first sight somewhat puzzling. Almost any sugary solution will contain them. If the juice of an apple is squeezed from the pulp, it forms a sweet liquid which tastes at first almost exactly like the apple from which it is taken. But if it is allowed to stand in a warm place a fermentation begins in it which rapidly changes its character, producing in a few hours what we call cider. A typical alcoholic fermentation has started, just as truly due to the growth of yeast as are similar fermentations in a brewery. Since the yeast has not been planted consciously in the cider, the fermentation must be due to the wild yeasts which find their way into the juice, either before it has been squeezed from the apple pulp or afterwards. The apple has been growing in the air for many weeks, and the wild yeasts have had plenty of chances to lodge on its skin. When the juice is squeezed from the pulp it is sure to contain these yeasts, and they promptly start a fermentation (Fig. 36).

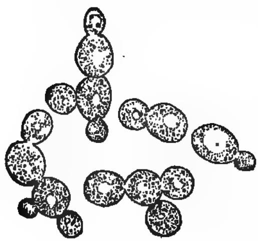


FIG. 36. Wild yeast from the juice of an apple, which causes the fermentation of cider.

In a similar way other spontaneously fermented products are made from the juice of various plants or fruits; for any sweet juice from such natural sources will be sure to become inoculated with wild yeast and will consequently undergo fermentation. This fact has been learned by almost all people from experience. Most savage tribes have learned to make fermented drinks from the juices of plants or fruits by simply collecting the sweet liquor and allowing it to stand until it ferments.

These wild yeasts explain another phenomenon occasionally seen in the household. The housewife finds that some of her preserved fruits or jellies at times undergo an alcoholic fermentation. This is quite different from molding or decay, and is found only in sugar-holding materials. The preserve develops a peculiar, sharp, pungent taste, easily recognized but difficult to describe. It is particularly liable to occur in jellies, partly because they contain much sugar, and partly because, even when covered in jelly tumblers, they are still somewhat exposed to the air and hence are liable to inoculation with wild yeast. Sometimes this phenomenon is also found in condensed milk and in canned foods that have not been properly protected. It is not uncommon to find a similar fermentation occurring in certain types of sugar. Maple sugar which is kept in the pantry for weeks, until it becomes moist, may ferment and develop the peculiar sour taste characteristic of this phenomenon. In all such cases the trouble is due to the presence of the wild yeasts which are floating in the air, and which settle and multiply upon any food suited to their growth. These wild yeasts are so sure to be present in the air that it is very difficult to protect a fermentable material from their action unless the air is completely excluded.

Such wild yeasts do not, of course, live permanently in the air, since the air would itself furnish no food for them. They live and grow in the soil, in decaying fruit on the ground, on the surface of fruit on the trees, and in a variety of other places. The air simply distributes them.

Food required by Yeast

All common species of yeast require sugar for food, and therefore will not grow rapidly unless sugar is present in abundance. Bread dough ferments because it contains some sugar. Flour itself contains a large amount of starch, which is not fermentable; but in the bread dough some of the starch is changed to sugar by a chemical process, so that fermentation is possible. Almost all sugar solutions furnish a proper medium for yeast growth, provided the solution is not too dense. Yeast cannot live upon absolutely pure sugar, since it needs certain other materials for food; but all natural sugar solutions, such as molasses, grape juice, etc., contain quite enough other material for the yeasts to feed upon, and they ferment readily enough. A high percentage of sugar is injurious to the growth of yeasts, a fact that explains why almost anything can be preserved if it is saturated with a large amount of sugar. (See Preserves, p. 183.)

Food is required for yeasts during the fermentation, since they are growing and rapidly increasing in abundance. The simple presence of yeasts produces no fermentation. If anything prevents the growth of the yeast plants, no fermentation occurs, and it is always found that the yeast increases in bulk during the process. In the large fermentative industries there is consequently produced a large quantity of yeast, which accumulates in bulk at the close of the fermentations.

This material has been mostly a waste product, although a considerable amount of it has been utilized for bread raising, as shown in the next chapter. Recently a new use for such masses of yeast plant has been found. In the course of its growth the yeast plant stores up considerable food material, and the masses of yeast that accumulate prove to be a useful food material. It contains not only the well-known types of food substance, proteins, fats, and carbohydrates, but also is well supplied with vitamins. Vitamins, as is well known today, are very necessary food substances, but of rather mysterious nature in that chemists have never analyzed them. It is known, however, that there are several vitamins, each serving its particular purpose in animal nutrition; not all of them are present in yeast, but enough to make it a useful article of diet. The various vitamins are distinguished by scientists by the letters A, B, C, and so forth. Our knowledge of them is constantly growing, and if recent claims are correct, that one of the vitamins has been isolated in chemically pure form, more accurate information about them will soon be forthcoming. In spite of all the recent investigations, however, it must still be admitted that our knowledge of their behavior in the body, as well as of their chemical nature, is still very imperfect. But it is known that they are necessary for health; and a diet without fresh vegetables, fruit, or milk is likely to be deficient in them. It is now well known that, when necessary, this deficiency may be made up, in part at least, by eating yeast; although for this purpose alone there is little demand for it in ordinary civilized communities, because it is much less palatable than fruits, vegetables, or milk products.

It is coming to be believed, however, that yeast has other properties as a food less well understood even than vitamins. Claims are even made that it overcomes constipation, controls certain stomach disorders, and improves the general tone of the body. To what extent these claims are based on fact and how far they are merely advertising propaganda cannot now be told for certain. It can, however, be safely stated that yeast is now being used to some extent as a food and is being widely advertised for the purpose. Commercial preparations containing yeast, so flavored as to be palatable, are now available, and may well in many cases be a desirable addition to the diet. Extracts of yeasts, under various trade names, have for some time been placed on the market in Europe, although not well known in this country. It is, however, doubtful whether they have the nutrient value of the yeast itself, any more than beef extract is as good a food as the beef.

CHAPTER VIII

YEASTS IN THE HOUSEHOLD

As Enemies. Yeast must, in general, be looked upon as the housewife's friend, since in almost all its relations to household affairs it produces only desirable results. In a few instances we find yeast producing trouble. Its occasional presence in jellies and preserves has already been noticed, as well as in the fermentation of maple sugar. Any sirup containing fruit sugar, cane sugar, or beet sugar may undergo spontaneous fermentation in our homes. In dairy products yeasts occasionally produce mischief, since the bitter tastes of milk and cheese are sometimes caused by their growth. This will rarely if ever trouble the housewife, although it may cause mischief for the dairymen. It is only in the fermentation of sugary substances, like jellies and sirups, that the housewife is troubled with undesired fermentation. One practical suggestion in this connection may be of use. Since boiling will kill yeasts, any material which shows the easily recognized sign of fermentation — the peculiar, sharp, pungent taste — can be preserved from further injury if it is merely heated to the temperature of boiling. No further fermentation will then occur, provided the subsequent entrance of yeast is prevented by protecting the material from the air. If the material cannot be heated, there is no satisfactory remedy for a fermentation once started.

As Friends. Yeasts must usually be looked upon as servants rather than as enemies. They are the allies of the housewife in a number of directions. We have noticed above that when they grow in sugar solutions they give rise to two new substances, carbon dioxide and alcohol, and in various domestic and industrial processes sometimes the one, sometimes the other, and sometimes both of these products are utilized.

The Use of Yeasts as a Source of Alcohol

The alcohol produced by yeasts is the foundation of the fermentative and distillery industries, for common yeasts are the agents which produce the alcohol found in all alcoholic beverages. The fermentative industries, which were important in this country before prohibition and are still of immense extent all over the rest of the world, are dependent upon yeasts. In the manufacture of fermented and distilled liquors these little plants are used in all cases for the production of alcohol out of various sugar solutions. The struggle with gigantic evils resulting from these industries forms one of the greatest problems of civilization. This, however, is a matter which does not belong to our immediate subject.

In breweries and distilleries some material containing sugar (molasses, preparations from rye, corn, barley, etc.) is inoculated with a quantity of yeast, a species being chosen which experience has shown to be well adapted to the purpose. The mixture is warmed slightly and a vigorous fermentation is started. The fermented mass may subsequently be used directly for a beverage — *fermented drinks*, like *beer*, *ale*, etc. — or the water may be partly separated from the alcohol by distillation, producing a liquor with a much higher percentage of alcohol, — the *distilled liquors*, like *rum*, *brandy*, *whisky*, etc.

In the making of *wines* the process is, in a way, simpler, and reliance is usually placed upon the wild yeasts which produce a spontaneous fermentation. The skin of the grape becomes the lodging place of numerous micro-organisms which collect there while the grape is growing. These include molds and bacteria as well as yeasts, and when the juice is squeezed from the grape it is certain to contain some of this wild yeast. Fig. 37 shows some of the wild yeast thus spontaneously inoculated into grape juice. The juice is set aside and a spontaneous fermentation begins. The fermentation is not very vigorous and may require many weeks for its completion.

So sure is the grape juice to contain yeasts that unless some means of preventing their growth is adopted fermentation cannot be avoided. In making what is called *unfermented grape juice* the yeasts are destroyed by heat. The grape juice is heated to a temperature of about 170° for a few minutes. This operation is usually performed twice, after which the wine is bottled and sealed. The process is really the same as that of preserving food by canning, which will be described later, the only essential difference being that the grape juice does not require boiling for its preservation. It will be noticed from Fig. 37 that there are other organisms besides yeasts upon the grape skin. These may have some effect upon the wine, and various devices are used to get rid of them.

Yeasts are also used in the manufacture of *homemade wines* which are produced from juices of fruit such as grapes, elderberries, blackberries, currants, raspberries, etc. *Cider* also is an apple wine. The principles in the manufacture of these homemade wines are the same as in the production of the commercial wines. It must be remembered that in the United States their sale or transportation is distinctly illegal.

Whatever be the source of the yeast, the process of wine making is simply an ordinary fermenting of the sugar. The carbon dioxide that is produced is allowed to pass off into the air undisturbed during the fermentation, and the liquid gradually becomes filled with alcohol. The final result is the wine, which always contains alcohol in small percentage. After the yeasts stop growing, bacteria may develop in the product and cause further changes, so as to injure its taste, or even totally change its nature, as in the formation of vinegar. (See Chapter XI.)

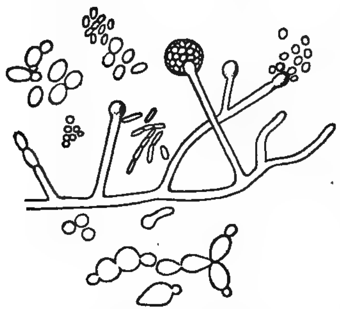


Fig. 37. Organisms found upon the skin of a grape and concerned in the fermentation of wine.

The Use of Yeasts as a Source of Carbon Dioxide

The chief use of yeasts in the household is not to produce fermented drinks but to raise bread. The *raising of bread* by means of yeast has been brought to a state of great perfection, so that the method of producing a desirable fermentation in bread dough by means of this product is now extremely simple. But it has taken many centuries of experiment and trial to understand the subject well enough to bring it under proper control.

In all nations, and apparently in all ages, people have been accustomed to make bread from meals obtained from the different kinds of grain. The earliest method of cooking such material was simply to mix it with water and then bake it, the result being a rather hard, tough material known as *unleavened bread.*

The next step consisted of a spontaneous raising of the dough. If dough is left in a warm place for a number of hours, it becomes somewhat swollen with gas, appears lighter in character, and when baked produces a type of bread more easily masticated, better in flavor, and more easily digested. Flour from most cereals, if mixed with water and kept for a few hours in a warm place, will undergo a fermentation, due to the wild yeasts that may have found entrance to the meal. This method of fermenting the dough gave the first form of *raised*, or *leavened bread.*

Very early, even before historical records, it was discovered that a little of the dough thus raised would serve as a starter for a second batch, resulting in a quicker and more satisfactory raising than that obtained by spontaneous fermentation. This was known as **leaven**, and as far back as the time of Lot we read of leavened and unleavened bread. The Egyptians also knew of this process. Leaven has been used from those early days to the present time. Even to-day leaven consists of a little dough which has already fermented and hence contains yeasts, and which is saved to be used in fresh dough for the purpose of starting fermentation. Although its use has largely given way to cultivated yeast, it has been employed in the baking of bread up to very recent times, and to a limited extent is still used in France. The difficulty with leaven is that its action is unreliable. The leaven contains bacteria as well as yeast, and these may make the bread sour, or sometimes bitter; and unless the very greatest care is taken in its manipulation the bread produced by means of it is not good. Only very skillful bakers can use it satisfactorily; but when successful, some think it makes better bread. The use of leaven has therefore been almost wholly replaced by the far more easy and reliable method of raising dough with cultivated yeasts.

The use of yeast instead of leaven in bread making is also old. In the time of the Roman empire it is apparent, from a few references in literature, that the use of yeast was understood. It is stated that the Romans in baking their bread sometimes used a leaven made of grape juice and millet for the purpose of hastening fermentation. We have already seen that grape juice is sure to contain yeast, and this phenomenon, whose nature the Romans, of course, did not understand, is perfectly intelligible to-day. The Romans were unconsciously using yeast for raising their bread. The early bakers soon learned to use yeast in a more accurate and satisfactory manner, and from the time of Rome down through the centuries the use of cultivated yeast products for the purpose of raising bread was more or less common. The methods of producing and cultivating yeast during these various ages are not known at the present time. It is known, however, that later the use of yeast declined, and bakers returned to the old method of using leaven. In the seventeenth century the use of yeast began again, and from that time on it has been used more and more widely. As methods of cultivating yeast developed it became possible to obtain a more reliable product, and as the reliability of the product increased so did its usefulness in a proportionate degree. At the present time yeast has very largely taken the place of leaven in baking, because it has proved easier to handle and more reliable in its results.

Methods of obtaining Yeast

The original source of all forms of cultivated yeast is wild yeast, which, as we have seen, may easily be obtained by exposing any sugary solution to the air. To obtain such yeast in quantity sufficient for the purposes of household fermentation, various devices have been practiced. Some of these, though little used at present, are instructive. A very interesting method of obtaining yeast called "salt raising" was frequently practiced by housewives before the introduction of compressed yeast. To a quantity of milk was added a little salt, sufficient to delay the growth of the common bacteria which otherwise quickly sour it. The milk was then placed in a warm place for several hours. The yeasts present in the milk were not injured by the salt, and therefore grew rapidly. The milk soon began to froth from the carbon dioxide thus developed. This material was then used to mix with the dough for the raising. The method here described has nearly gone out of use, and no study has been made of the kinds of microörganisms actually concerned in the process, though it probably involved both yeasts and bacteria. It is interesting to-day simply because it was a method of utilizing the wild microörganisms for the purpose for which we now use cultivated yeasts.

Other devices obtained by spontaneous fermentation have frequently been practiced. Bakers sometimes make a brew which is allowed to ferment spontaneously, and use the product for bread raising. In making the *Scotch barms*, a brew is prepared containing hops and flour, with other ingredients, and this, at least in making "virgin barm," is allowed to ferment spontaneously.

In all such cases yeasts are obtained, but they are always mixed with bacteria, which may materially interfere with their successful working. The uncertainty of results due to these impurities has led to cultivating yeasts especially for household purposes. Cultivated yeasts are simply wild yeasts from the air which have been freed from impurities and planted in some pure food material, where they grow in abundance, giving finally a mass of pure yeast. Cultivated yeasts are now used almost universally by all bread makers because of their greater reliability.

Fermenting Power of Different Yeasts

The cultivated yeast used to-day in bread raising has been gradually selected from a large variety of species. The microscopist recognizes many different kinds of yeasts, varying in their microscopic appearance, their rapidity of growth, and their power of producing fermentation, as well as in other important characteristics. Most of them will raise bread, but some of them are poorly adapted to this purpose. Some of them, like brewer's yeast, act so slowly that the bread will not rise rapidly enough.

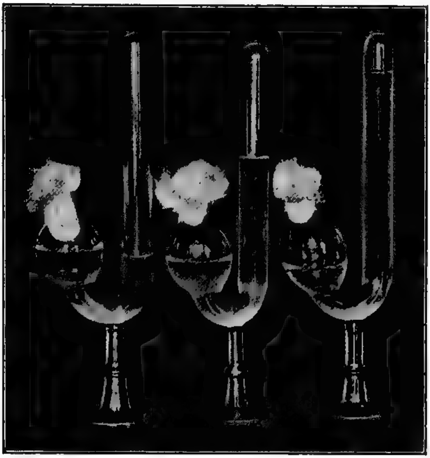


FIG. 38. Three fermentation tubes inoculated with different varieties of yeast, showing the differences in fermenting power, as indicated by the amount of gas collected in the closed tube. The tube on the right was inoculated with dried yeast, the middle tube with brewer's yeast, and the left-hand tube with compressed or distillery yeast.

The use of yeast in bread making is dependent entirely upon its fermentative power, and consequently the value of any type of yeast will depend upon the energy of its fermentation. Some types of yeast produce a more vigorous fermentation than others. The cake of compressed yeast, for example, produces a more vigorous fermentation in bread than either the brewer's yeast or the dried cake. The relative value of the three types in fermenting flour is shown in Fig. 38. In each tube was placed a mixture of flour and water so as to fill completely the closed arm on the right. Each was then inoculated with a different yeast, the same quantity in each. As they fermented the sugar in the flour, the gas given off collected in the closed arm as shown, and the vigor of the fermentation may be inferred from the amount of gas produced. It will be seen that the tube on the left has in the inclosed arm a much larger amount of gas than is found in either of the other samples. This tube was inoculated with a distillery yeast (compressed yeast), and the experiment shows that this type of yeast has a greater fermentative power upon flour than either of the other two forms. It suggests also that this yeast will be the most satisfactory for the ordinary domestic purpose of bread raising.

There are also other factors concerned in the choice of a proper species of yeast. Some kinds of yeast give a sour or otherwise unpleasant taste to bread, and others give to the bread an undesirable color. From the many varieties of yeast which might be used for this purpose certain ones have been chosen by the brewers as particularly well adapted for their type of fermentation; others are commonly used in distilleries. But this does not necessarily make them the best for bread raising. A long experience in baking has resulted in the selection of the type best adapted for bread raising, and this is a species that grows quickly in dilute sugar solutions and hence raises the bread in a few hours. At the same time it gives rise to a pleasant, agreeable taste, and produces no color. Consideration of all these phenomena has been clearly essential in selecting a yeast which is best adapted for bread making.

All of the yeasts used by brewers and distilleries to-day belong to the same species, and this species is also the best for bread raising. But although all one species there are several quite distinct varieties having different fermenting powers.

Different Kinds of Commercial Yeast Preparations

In the early periods of bread making there were no means of obtaining pure yeast. Gradually, however, we have learned to cultivate the yeasts by themselves, until at the present time there are quite a number of methods for producing tolerably pure masses of yeast. The chief preparations of this sort are given in the following pages and all one species, known as *Saccharomyces cerevisiæ;* but although belonging to one species there are a number of varieties differing in several characters.

Compressed Yeast. At the present time the yeast most commonly used by the housekeeper is the compressed yeast cake. This well-known commercial article consists of a soft, somewhat soggy material, composed of large quantities of yeast plants mixed together with a certain amount of starch and a varying quantity of other material. This yeast is originally a distillery yeast, which the manufacturers of certain alcohol products sow in large vats containing materials upon which the plant feeds readily. The yeast multiplies rapidly and after a few hours collects as a scum on the surface of the vat. This is removed, washed, and the water partly removed by heavy pressure; then the mass is formed into cakes and sold to the public.

This compressed yeast is the most convenient and reliable type of yeast culture that has been produced. In the fresh cake nearly all of the yeast plants are alive and vigorous, and the results obtained from their use are almost uniformly satisfactory. Compressed yeast has one disadvantage: it will not keep long, and hence must be used while fresh or the proper results will be lacking. If the yeast cake is kept for a day or two only, the plants begin to die, and after three or four days only a small number of them may be left alive. Such yeast when a few days old will not produce as quick a raising of the bread as the fresh cake. More than this, a result is frequently experienced in old cakes that is worse than the loss of activity. The commercial compressed yeast is never a pure yeast, but contains a variety of other microscopic plants, among which are bacteria as well as other yeasts. These other organisms are liable to grow in the cake if kept for a few days. The yeast may even decay, which indicates an excessive growth of bacteria; but if it does not decay it is quite certain that in an old cake other kinds of yeast or bacteria are relatively more abundant than they are in the fresh cake. When such an old yeast cake is used it may give rise to undesirable fermentations in the bread, resulting in unpleasant flavors. If it is necessary to keep a compressed yeast cake some days before using it, it is best preserved by placing it in cold water and keeping it on the ice; but it should never be allowed to freeze.

Where the compressed yeast cake can be obtained fresh, however, it is the most convenient form in use. It is so cheap that the expense need not be considered in the household, where only a small amount is needed. But where large quantities of bread are to be made, compressed yeast is rather expensive, and it may be cheaper then to brew one's own yeast. Consequently bakers long adhered to their own methods of making yeast, to be referred to presently, instead of depending upon the commercial product. For the ordinary housekeeper the bother of making the yeast brew is so great, the results so unreliable, and the expense of compressed yeast so slight, that the latter is now almost universally used. To-day many bakers have given up making their own yeast brews and depend upon compressed yeast.

FIG. 39. Yeast from a dried yeast cake.

Dried Yeast. A second type of commercial yeast is the dried yeast cake. This is prepared by cultivating yeast, mixing the product with certain ingredients, chiefly starch, pressing into cakes, and then drying the product at a low heat. The drying perhaps injures or kills some of the yeast plants, but a great many of them remain uninjured, and may be found for a long time in the dried yeast cake, still alive and capable of growing if placed under proper conditions (Fig. 39). In order that they may begin to grow again they must be moistened, and in using a dried yeast cake it is best to soak it in warm water to which has been added a small amount of sugar. The sugar furnishes food for the yeast plants, and by soaking them in warm water they are soon brought to a condition of growth, so that when added to the bread dough they readily enough produce a fermentation (Fig. 40).

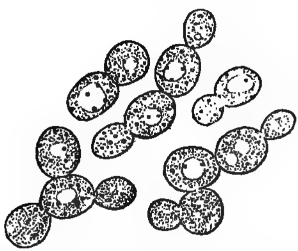


FIG. 40. The same yeast after a few hours' growth.

The dried yeast cakes are not quite so convenient to use as the compressed, but a little experience will enable any one to obtain good results with them. Their great advantage is that they need not be absolutely fresh. The cakes may be preserved for many weeks or even months, and their powers will not be destroyed. They cannot decay or mold, since they contain little water. It is always well to remember, in using them, that the drying of the yeast destroys some of the yeast plants and in time kills them all. If such a yeast cake is examined week after week, a decreasing number of living yeast plants will be found, and finally they will all disappear. The fresher the cakes are, the better; and those that are very old are useless. But in spite of this fact these dried yeast cakes may be kept for many weeks, and for persons who have not a ready access to a market they are much more convenient than the compressed cakes.

Sometimes yeast is prepared in the form of a **dry powder.** It is not a very common form, and the statements made concerning dried yeast cakes will apply equally well to yeast powder.

Brewer's Yeast. Yeast has frequently been sold in a liquid form by brewers to bakers, to be used in raising bread. Yeast from such a source is different in variety and action from that of the compressed or dried yeast cake. It grows in the brewer's fermenting vats, either as the "top" yeast or the "bottom" yeast. The former grows as a scum on the top of the vat, while the latter sinks to the bottom, the former alone being used for bread raising. The first that appears on the surface of the vat is commonly removed, since it is liable to be filled with dirt and harmful bacteria. The flavor of bread raised with brewery yeast is a little different from that raised by other kinds, and is sometimes slightly bitter, thus explaining the difference sometimes noticed in the flavor of baker's and homemade bread. This type of yeast does not produce so vigorous a form of fermentation in flour as compressed yeast, and is less satisfactory in a household. Its use even by bakers has largely ceased.

Cultivation of Yeast Brews. When one is near a market, by far the most convenient method of obtaining yeast for bread making is to purchase the compressed cake; but when one is far from market a fresh supply is not easily obtained. Moreover, we have noticed that if yeast is needed in large quantities the compressed yeast is somewhat expensive. It is then certainly cheaper and may sometimes be more convenient to brew one's own yeast. Brewing yeast is a very easy process if one will exercise a little care.

First one prepares a mixture known as the *brew*, in which the yeast will grow readily; and then he inoculates this mixture with a small quantity of yeast from some good source and allows the material to grow. Many varieties of mixtures are in use for the development of yeast. Two good formulæ are as follows.

(1) 1 lb. potatoes	(2) ½ lb. of malt
½ oz. hops	½ oz. of hops
1 gal. water	1 gal. of water

To prepare the first of these mixtures, boil the potatoes and remove the skins; boil again until thoroughly soft, and then mash finely. Meantime the hops are to be heated with the water to nearly the boiling point for a couple of hours, to dissolve the hop extract. After this the liquid is to be strained and mixed with the mashed potatoes. It is well to boil again for a few moments to destroy any microscopic organisms (bacteria or molds) that may have found entrance into the brew during its preparation. The material is then to be cooled and may be allowed to ferment spontaneously. But, since the results are then unreliable, there is usually added to it, after it is cooled to the temperature of 70° to 80°, a small quantity of pure yeast from some reliable source. The whole is to be stirred occasionally and allowed to stand until the yeast has developed for a few days. The yeast will then be present in large quantity in the brew, and can be used for any desirable purpose.

In making the second of the above brews, the process is nearly the same. The hops are steamed or heated with the water, as in the first case, and then mixed with the malt according to the proportions given in the formula. The subsequent treatment is identical in both cases.

Some such method of preparing yeast was in former years almost universally used for baking. Brewing yeast is inexpensive, simply requiring a little care; but with the introduction of the convenient compressed yeast at a small price this method of making yeast has practically disappeared from the household. It is still retained, however, in some places where large quantities of yeast are used.

The hops are added to these brews, not as food for the yeast, but for two other purposes: (1) They give a slight nutty flavor which is subsequently imparted to the bread, somewhat improving its taste. (2) The extract of hops is a partial antiseptic, in a measure preventing the growth of bacteria, though not injuriously affecting yeast. Without the hops various mischievous bacteria would be almost sure to develop in the brew, injuring or perhaps ruining it. The slimy-bread bacterium, for example (see page 111), is liable to grow in these brews, but the hop extract has a decidedly antiseptic power against it.

By a method somewhat similar to the above, breweries and distilleries cultivate yeast; but in these large establishments, where there is a demand for large quantities of yeast of the highest grade, a care is given to the brewing impossible in the home. The brewer uses a microscope to test his product, and exercises a care in cultivating his yeast which insures its purity. Yeast from such sources is therefore more reliable than any other, and consequently most yeast in use to-day comes from breweries or distilleries, or from institutions where it is grown upon a large scale. Home brewing of yeast is unreliable and unsatisfactory.

CHAPTER IX

BREAD RAISING; FERMENTED LIQUORS

What is Bread Raising?

The method by which yeast makes bread light is very simple and easily understood. There is present in the bread dough, at the start, a small amount of sugar which comes from the flour; but there is, in addition, a considerable quantity of starch, and with the starch there is also present in the flour a small amount of a material known as *diastase*. By the action of this diastase in the dough, part of the starch is converted into sugar. Thus there is present in the dough, after it is mixed, a sufficient quantity of sugar to furnish proper fermentable material for the yeast.

Fig. 41. Recently mixed dough inoculated with yeast, but before the yeast has grown.

The baker mixes the fresh, active yeast with the dough, and places the whole in a warm place where the yeast will be stimulated into active growth (Fig. 41).

The yeast begins to feed upon the materials in the dough and ferments the sugar, producing carbon dioxide and alcohol. Both of these materials remain for a while in the dough, the alcohol dissolving in the water, and the carbon dioxide accumulating as a gas in small bubbles. The dough is so sticky and heavy that it is not possible for these bubbles to rise up through the dough as it does in ordinary fermented liquids (Fig. 31). The gas, therefore, simply collects as small bubbles in the midst of the dough, causing the dough to swell. This is the so-called *raising* of the bread, and the bread maker must learn from experience when it has progressed sufficiently. After the dough has been properly "raised" by the yeast, it may be seen to be filled with holes occupied by the gas bubbles (Fig. 42). Now, after the proper kneading, it is sometimes baked at once and sometimes given a second raising. The heat of baking drives off the small amount of alcohol. The heat also expands the bubbles of gas so as to enlarge the little holes in the dough, thus causing it to swell still more; but while this is being done the heat hardens the dough into the firm texture of the baked bread, and the holes previously occupied by the

FIG. 42. The same dough after yeast has grown and caused the dough to swell up by the accumulation of carbon dioxide.

carbon dioxide gas are left as pores in the bread (Fig. 43). This makes the bread light and porous, and gives it the character that every one is familiar with in properly raised bread. If it were not for these holes, the dough would be a hard, tough mass, difficult to bake and more difficult to digest.

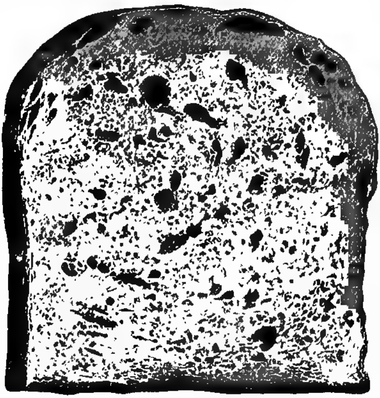


FIG. 43. The same material after baking, showing the cavities left after the carbon dioxide is expelled.

The purposes of the raising of bread by yeast are three.

1. It makes the material *lighter*, i.e. more porous, and hence easier of mastication and more palatable.

2. It renders it *more digestible*, because the porous material is more easily acted upon by the digestive juices than the more solid unleavened bread.

3. The yeast imparts a certain *flavor* to the bread which enhances its value. This flavor, due to yeast, is well shown by the difference in the flavor of bread raised in the ordinary household and that sometimes raised by bakers, where a different species of yeast is used.

That the flavor produced by yeast is an important factor may be realized also by comparing the flavor of bread raised by yeast with that made light by chemical or mechanical means. Any process which will fill the dough with bubbles will make it light. In one type of bread, known as *aërated bread*, the spaces or cavities in the dough are produced by mechanically mixing air with the dough. The result is a bread that is light enough but lacks the peculiar flavor present in ordinary raised bread. In another type of bread (*quick biscuits*) chemical means are relied upon to produce the gas. A small quantity of cream of tartar and saleratus is mixed with the dough. These two materials act upon each other chemically and give rise to a quantity of carbon dioxide gas, which appears very quickly, and rapidly fills the dough with bubbles of gas. The dough, when subsequently baked, is light, but has a flavor quite different from that which would be produced in the same dough if it were raised by the action of yeast. No other method of producing lightness in the dough gives quite such flavors as can be obtained by the use of yeast, and none is thought to make bread quite so easy of digestion.

Relation to Temperature

The growth of yeast, and hence the raising of bread, is very closely dependent upon temperature. Yeasts grow readily in warm temperatures, less readily in low temperatures, and not at all if the temperature is in the vicinity of freezing. Common yeast grows best if kept between 75° and 90° F. At higher temperatures the yeast does not produce such good results, since certain other injurious microörganisms (*bacteria*) are then likely to grow. If the dough is kept at a temperature above 90°, there is almost sure to be trouble from the growth of undesired organisms which give rise to unpleasant flavors. Bread made from such dough is very apt to be sour. The temperature should be higher in winter than in summer, owing partly to the fact that flour in winter is quite sure to be cold and to require some time to become warm. In winter a temperature of 95° is not too great for the proper raising of the dough, while in summer a temperature of 70° is more satisfactory. In the raising of bread dough it is always far better to use a thermometer and to determine the exact temperature. This is rarely done in the ordinary kitchen. It is more common to place the dough near the stove and trust that the temperature will be close enough to that desired. It is not possible, under these circumstances, to depend absolutely upon the results. In the majority of cases the dough is fermented satisfactorily, but bad batches of bread from this cause are a frequent experience of the housewife. To produce uniform results it is quite necessary to use a thermometer, and then the dough may surely be kept within the limits of temperature above mentioned.

The length of time for yeast to grow in the dough before baking is dependent upon the temperature of the fermentation; but it is important that it should not be too long. If the temperature is low (below 70°), so that it requires a longer time than usual for the dough to rise sufficiently, the texture of the bread is apt to be crumbly and brittle, and a sour taste is very likely to develop, due to the growth of other microörganisms besides the yeast. If, on the other hand, the bread rises too quickly, owing to too high a temperature, an abundance of gas is produced which makes the dough rise rapidly; but the bread will be inferior in flavor, texture, and color. The best results are obtained by a moderately active growth of the yeast, which will produce a sufficient amount of lightness in the dough in the course of eight or ten hours.

Impurities in Commercial Yeast

One factor largely determining the value of commercial yeast is its purity. It rarely or never happens that a yeast cake, or yeast culture of any form, is composed purely of yeast. There is almost certain to be mixed with it a quantity of bacteria. Frequently there is also present a variety of mold spores, and especially in summer the yeast cake is likely to contain other species of yeast besides the one desired for bread raising. These impurities may be abundant or scanty in any cake of yeast. If they are present at all, they may produce trouble, but this will depend upon circumstances. The yeast plants themselves are present in such overwhelming proportions that, under ordinary circumstances, the impurities get little opportunity to develop. If the raising is conducted at a proper temperature, the impurities will rarely do much injury. In the common use of yeast, therefore, in spite of the fact that various bacteria and mold spores may be mixed with the dough when the yeast is added, the bread rises in a normal way, and the impurities produce no trouble.

These foreign bacteria in the yeast cake are quite sure to increase with its age. While the yeast plants do not multiply in the compressed yeast cake, the bacteria are almost sure to do so, especially if the cake is kept in a moist condition for some days before using. An old yeast cake is therefore quite sure to contain more of these impurities than a fresh one. Moreover, in an old cake, as we have seen, the number of living yeast cells is less than in a fresh one, and so the undesirable germs have a better chance to grow in the dough. The use of an old yeast cake is therefore unwise, since the bread may thus be ruined. The fermentation does not progress rapidly enough, the bread must be kept longer at a warm temperature, and during this whole period the other yeasts or bacteria have a chance to develop and produce a variety of bad flavors. If one uses fresh yeast cakes, there is little probability that any trouble will arise from the action of the smaller number of bacteria or molds that may be present.

Sour Bread. The impurities from the yeast or from some other source do, however, occasionally produce trouble, two types of which are so common as to demand notice. The raising of dough by means of yeast sometimes causes it to become sour. The dough rises in the proper manner apparently, but the bread when baked is found to have an unpleasant, sour taste. This is especially likely to happen if the bread is raised too long. By some this sour taste is regarded as an improvement to the flavor. It is due to the development, during the fermentation, of certain acids in the dough, which come, not from the action of yeasts, but from the growth of bacteria that are present either in the yeast or flour. It has been a disputed question whether the acid produced is *lactic*, *acetic*, or *butyric*. (Lactic acid is like that formed in sour milk, acetic acid is formed in vinegar, and butyric acid is the acid found in old rancid butter.) It is frequently a mixture of all three, but ordinarily it is probably mostly lactic acid. Each of these acids is known to be produced by bacteria. Since the acids are caused by bacteria, this subject really belongs to a later division of our discussion; but its close relation to bread making leads to its introduction at this point.

Recognizing that the cause of sour bread is due to the growth of bacteria, it is not difficult to suggest the proper means of avoiding it. Fresh yeasts only should be employed. A good quality of flour should be used, and the dough should be mixed in clean utensils. After mixing, the dough should be placed in a clean dish at a proper temperature (75° in summer, 90° in winter), so that the bread will rise in about eight hours. Dough should never be allowed to ferment too long. Strict attention to these details will commonly remove the trouble.

The bacteria which produce sour bread do not, however, come wholly from the use of impure yeasts, for the flour itself is likely to contain some organisms which may cause this trouble. A sour taste is much more likely to be found in bread made from poor grades of flour than in that made from the higher grades. This is perhaps due to the fact that, owing to difference in the method of manufacture, the lower grades of flour contain a larger number of bacteria. The same trouble is also sometimes caused by the use of unclean utensils in the mixing of the dough, or by leaving the dough to rise in a dish not thoroughly washed. Unclean utensils are sure to have a large number of bacteria attached to them, and these bacteria, becoming mixed with the dough, grow there readily side by side with the yeast.

Slimy Bread. It has been noticed that, a few hours after baking, bread sometimes becomes slimy in consistency.

When perfectly fresh it does not show any sliminess, but after standing a few hours the inside of the loaf appears more or less moist, and shows a slimy texture when broken, looking as if permeated with cobwebs. This trouble is occasionally met with in the household, but more commonly in bakeries. Indeed, sometimes sliminess has become so troublesome in certain bake shops as nearly to ruin the business, the trouble reappearing day after day and proving extremely difficult to remedy.

The cause of the trouble is known to be the development of certain bacteria, one species of which is shown in Fig. 44. These bacteria are capable of growing in the dough, and are not killed during the baking. After the bread is removed from the oven they begin a rapid growth, if the bread is kept warm, and in a few hours produce the trouble described. These bacteria frequently come from the yeast cake, but in some cases, where the subject has been studied in detail, it has appeared that the source is the flour rather than the yeast. Certain samples of flour contain these mischievous organisms, and when bread is made from such flour it is difficult to avoid their presence and growth. A change to a new brand of flour will then obviate the trouble. If a housewife should experience this slimy bread fermentation, the proper method of procedure is (1) to use a new brand of flour for bread making, (2) to sterilize, by methods to be referred to later, all utensils that are used in connection with bread making,

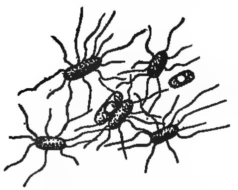


FIG. 44. A species of bacterium which produces slimy bread.

and (3) to get a fresh supply of yeast. After this the trouble ought to disappear. It is also important to remember that the sliminess occurs only if the bread is kept warm, and hence chiefly in the summer. If the bread is cooled at once and kept in a cool place until it is eaten, the trouble is not likely to manifest itself even though the slimy bacteria are present. The bread is wholesome enough even though slimy.

The Utilization of both Alcohol and Carbon Dioxide

In the production of *beers*, *porters*, *ales*, etc., both of the products of fermentation are commonly utilized. The general character and effect of beer are due partly to the alcohol present and partly to the presence of a quantity of the carbon dioxide, which gives to the beer its sparkle. In the manufacture of such a product the fermentable material, usually some form of grain, is inoculated with a large quantity of a vigorous yeast, a species being chosen that has been found by experience to produce the desired results. A fermentation starts up which progresses rapidly if the temperature is kept warm, as it is in the manufacture of common beer. The process lasts from a few days to several weeks according to temperature and the kind of beer being made. During this fermentation alcohol accumulates in the liquid, and the carbon dioxide gas escapes into the air, forming a froth in the fermenting vat. The yeast increases in amount, and either collects on the surface or sinks to the bottom. Most of the yeast is then removed, and the liquid stored in casks or bottles. Here the fermentation continues for a time, but rather slowly. Since the vessels are closed the carbon dioxide gas cannot escape, but, accumulating in the vessel, is partly dissolved in the liquid itself. The gas exerts considerable pressure inside the bottle or cask, and when it is opened the expansion of the gas gives rise to the popping of the corks and the bubbling and frothing of the beer; in other words, to the sparkle. In beers the carbon dioxide is desired no less than the alcohol, since it contributes materially to the flavor of the product. In ordinary wines, however, the fermentation is allowed to continue for a much longer period and the gas permitted to escape; hence the alcohol content becomes high and the drink has no sparkle.

Such fermentations form the basis of immense industries in other countries, and did in the United States before prohibition. The present law has resulted in much more home production of fermented drinks in this country than ever before, especially of wines. The fermentative process, however, should be given more careful control than can ordinarily be managed in the home; and such home brew seldom recommends itself to any except those who crave alcohol in any form.

There is, however, a type of *homemade beer* which is easy to make and is ordinarily too low in alcohol to be intoxicating or to come within the scope of prohibition legislation.

In previous years this was made from certain roots and extracts of strongly flavored plants. For example: home beers have been made from a mixture of molasses and hops flavored with spruce extract; or sugar and ginger with lemon for flavor; or a mixture of sugar, crushed raisins, and lemon; but to-day highly flavored extracts are purchasable at stores for a small price. These flavoring extracts are mixed at home with a quantity of sugar and water (two pounds sugar to ten quarts water). To the mixture is added a small amount of yeast (one cake of dried yeast or $\frac{1}{3}$ cake of compressed yeast for the above quantity), and the whole material, closed in bottles or other vessels, is then set aside in a warm place for fermentation. The fermentation goes on rapidly, and in the course of a couple of days a beverage is produced, filled with carbon dioxide, which causes a bubbling and frothing when the vessel is opened, and containing a small quantity of alcohol. To keep the alcoholic content low one should consume the beverage promptly, or one should put it in a very cold place after one or two days' fermentation. As a matter of fact, although the fermentation may be allowed to continue longer, this is

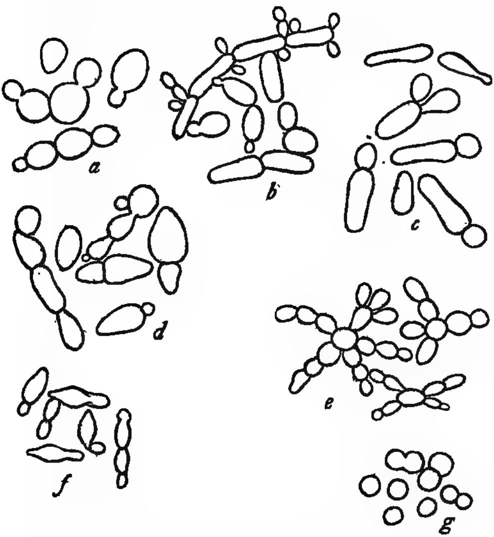


FIG. 45. Miscellaneous species of yeast.

a, *S. cerevisiæ*; *b*, *S. pastorianus I*, from wine; *c*, *S. pastorianus III*; *d*, *S. ellipsoideus II*; *e*, *S. cerevisiæ*, from beer; *f*, *S. apiculatus*; *g*, *S. minor*.

hardly a desirable way to obtain an alcoholic drink if one is desired; for the flavor of such a brew after longer fermentation in no way resembles that of commercial beer, and is generally regarded as rather unpleasant.

In making such home-brewed beer it must be remembered that the fermentation, which results in the production of carbon dioxide and alcohol, is due to the action of the yeast upon the sugar and not to the beer extract. The extract is added in these cases chiefly to produce a peculiar flavor in the product, which renders it palatable. The commercial beer extracts simply give a pungent taste and perhaps stimulate the growth of the yeast; but it is the fermentation of the sugar that causes the sparkle due to the carbon dioxide, and any sugary solution will ferment in a similar way if yeast is added. The product is not palatable, however, unless something is present to give it a flavor. The only reason why such homemade beers are less intoxicating than commercial beers is because the fermentation is allowed to continue but a short time, long enough to produce an abundance of carbon dioxide but only a little alcohol.

Homemade beers of this type are probably less popular to-day than formerly, largely because of the wide variety of comparatively inexpensive charged drinks sold in bottled form. These bottled drinks are not fermented, but are artificially charged with carbon dioxide so as to give them the sparkle of beers without the alcohol. Some of these charged drinks, like ginger ale, birch beer, and root beer, are much the same in taste as the old-fashioned homemade beers; while others of the "near-beer" type more closely resemble the commercial beer now forbidden in this country by law, having the flavor and the sparkle, but lacking the alcohol.

Fermented Milk. A mild fermented beverage is occasionally made from milk by means of a yeast. It is called *kumiss*, and is regarded as useful for invalids, since it is supposed to be more easy of digestion than raw milk. Its preparation is as follows. Into a quantity of milk is placed a little common sugar,— from four to eight tablespoonfuls to a gallon of milk,— and yeast is added just as in homemade beer, one fourth of a cake of compressed yeast in a little water being sufficient for a gallon of milk. The mixture is put in a warm place and fermentation sets in. After twenty-four hours' fermentation the material is bottled and placed on ice; when cool it is ready for use. The milk becomes slightly soured, giving a taste much relished by some people. It is filled with carbon dioxide and contains a small amount of alcohol, and is thus a sort of beer made from milk. It is not much used in this country except for invalids. Other types of fermented beverages, *kefir*, *matzoon*, and some others, are made from milk by the use of special ferments, always containing yeast, whose preparation is hardly within the reach of the ordinary household.

SECTION IV — BACTERIA

CHAPTER X

THE GENERAL NATURE OF BACTERIA

Our study of bacteria must be more extended than that which we have given to either molds or yeasts. While molds and yeasts are of significance in the household, the action of bacteria is much more fundamental and universal.

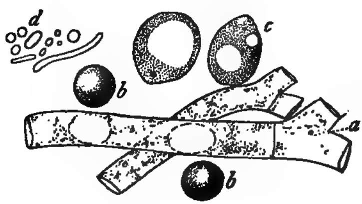


Fig. 46. Showing the comparative size of molds (*a*), yeast (*b* and *c*), and bacteria (*d*).

Bacteria are far smaller than yeasts or molds (Fig. 46). Some housewives do not know of their existence, while even those of the more intelligent class often fail to appreciate their close relation to household economy. Few housewives, it is safe to say, have ever seen them or been aware of their existence. Nevertheless they are so constantly at work upon all kinds of food products in the pantry, that the affairs of the household are in a state of more or less constant warfare against these invisible, unrecognized, and unknown foes. They are more serious enemies than molds or yeasts. Chiefly to their presence and activity is due the fact that the preservation of foods, even for a few days, is frequently difficult, while special devices are required to preserve food indefinitely.

To the housewife bacteria are of little value and are foes, like the molds, rather than allies, like the yeasts. This does not mean that they have no utility. On the contrary, they are of the most fundamental importance in nature, and it is no exaggeration to say that the very continuation of life is dependent upon their activity. To the farmer they are absolutely essential. They are the dairyman's close allies, and they are indispensable friends of many industries. By their action are produced some of the articles for our tables (vinegar) and also the flavor of butter and cheese. However, these phenomena do not directly concern the housewife, and, with a few individual exceptions, bacteria are her foes.

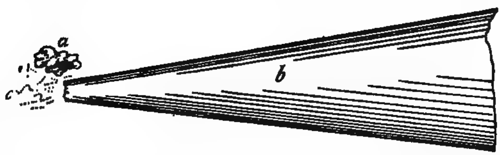


FIG. 47. Comparative size of the point of the finest cambric needle (*b*), a particle of dust (*a*), and bacteria (*c*).

STRUCTURE OF BACTERIA

Size. Bacteria are much smaller than yeasts, and only the high powers of the microscope can disclose their presence (Fig. 47). Many are not more than a fifty thousandth of an inch in diameter, and even the larger ones are not much more than a ten thousandth of an inch. But bacteria are far more abundant in nature than yeasts. They are present in great numbers in the earth, the air, and the water, and are sure to find their way into every kind of food or anything else that may be exposed to the air. They are also much more troublesome than molds for two reasons: (1) they multiply with a rapidity that is quite inconceivable; (2) they are quite invisible to the naked eye, and their presence is not suspected until they become numerous enough to produce undesired changes in the material upon which they are growing. As a result they present a vast number of problems to the housewife, which she has dimly seen for years, but for which science has only in the last few years begun to offer solutions. They are much more difficult to handle than either molds or yeasts, because they are smaller, more numerous, and more vigorous, and for these reasons it is almost impossible to exterminate them. It is an impossibility to free a pantry from bacteria and very difficult to guard food from their action.

Shape. Bacteria are very simple, and there are such slight differences between the various kinds that in many cases it is quite impossible by microscopic study to distinguish one species from another. The bacteriologist knows to-day that many bacteria which when studied under the microscope appear absolutely identical, are totally unlike in their general characters. It frequently happens that perfectly harmless bacteria cannot by ordinary microscopic study be distinguished from those that are very harmful. For example, the bacillus which produces typhoid fever cannot be distinguished microscopically from another common but harmless species found in water. For this reason the microscopic study of these plants gives only a small part of the facts that we need to know in regard to them.

Classification. A consideration of the classification of bacteria is quite unnecessary for the purpose of our work, inasmuch as they are so minute that no one without the aid of a powerful microscope will ever be likely to see these organisms. Their activities are seen on all sides, but the organisms themselves are totally below the reach of our vision. It is sufficient, therefore, to give a few facts concerning their general appearance.

Bacteria are the simplest organisms known. They are far simpler than molds and even simpler than yeasts. So minute are they, and so simple in their structure, that very little is known in regard to them at the present time except their external appearance. They are almost universally regarded as *plants*, although many of them are endowed with a power of motion and for this reason might readily be mistaken for animals. Biologists have learned, however, that many plants can move; bacteria need not, therefore, be classed with animals on that account if they resemble plants more closely in other respects.

Flagella. The fact that many bacteria are endowed with the power of motion suggests that they must have locomotive organs, and these, indeed, are easily seen by proper microscopic study. They consist of minute hairs which project from the body of the bacteria. Sometimes there is a single one from one end, sometimes they occur in tufts, and occasionally they may be scattered all over the bodies of the bacteria as shown in Fig. 48. These little hairs are capable of waving to and fro, and by this motion they drive the bacteria through the water. Not all bacteria possess such locomotive organs, and one means by which scientists classify these organisms is by the presence or absence of these motor hairs. They are known by the name of **flagella.**

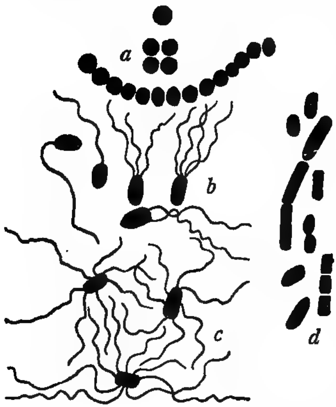


FIG. 48. *a*, cocci; *b* (*Pseudomonas*), rods with polar flagella; *c*, rods with peritrichiate flagella; *d*, immotile rods.

Spherical Bacteria: Cocci. The simplest type of bacteria consists of those that are in the shape of a minute sphere. Their size differs somewhat, but they are always extremely minute, and about all that can be said in regard to them is that they are spherical organisms, sometimes possessing flagella and sometimes apparently without them. No internal structure is known. They multiply sometimes in such a way as to produce long chains (Fig. 49, *a*), sometimes so as to produce groups of fours or groups of eight or sixteen (Fig. 49, *b*, *c*, *d*). The general name given to spherical bacteria is **coccus**, and to this name are sometimes prefixed certain other syllables to indicate certain characters. *Streptococcus* is a name given to cocci forming chains (Fig. 49, *a*), and *Micrococcus* to those forming fours or irregular masses as at *b*. The term *Sarcina* is the name given to those that form solid masses such as shown in Fig. 49, *c* and *d*.

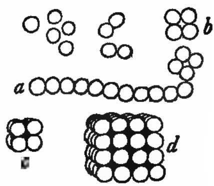


FIG. 49. Cocci, showing methods of multiplication. *a*, *Streptococcus*; *b*, *Micrococcus*; *c* and *d*, *Sarcina*.

Rod-shaped Bacteria. These are in the shape of rods of greater or less length. They are usually somewhat rounded at the ends and may be only a little longer than they are broad, or they may be very many times as long as broad (Fig. 50). When one of these grows it lengthens and commonly soon divides into two, but they may continue to lengthen for a time without manifesting any signs of division.

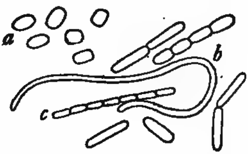


FIG. 50. Rod-shaped bacteria.

In such a case they form long slender threads, as shown in Fig. 50, *b*. These threads, however, eventually break up into short sections (Fig. 50, *c*). Some of these rod-shaped bacteria have flagella and are capable of active motion (Fig. 48, *b*, *c*); others have no flagella and are quite without the power of motion (Fig. 48, *d*). Several names are given to bacteria of this shape; *Bacterium* and *Bacillus* are two of those most commonly used.

Spiral Bacteria. A third type of bacteria is in the form of a spiral rod, shown in Fig. 51. These, however, are somewhat uncommon and of less importance than the others. Like the other forms they may possess flagella or they may be without them.

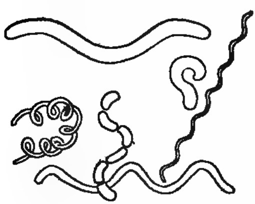


FIG. 51. Spiral bacteria.

Multiplication. The growth and multiplication of bacteria is extremely simple and consists in a lengthening of the individual followed by its division. A sphere becomes slightly oval in shape and then divides in the middle to produce two spheres, as shown in Fig. 52, *a*.

One of the rod-shaped forms lengthens itself and divides in the middle and produces two individuals, each of which again lengthens and divides (Fig. 52, *c*, *d*). The same method is found in the spiral bacteria. This manner of division, which is characteristic of all bacteria, will be seen to be quite different from the method we have already noticed in the yeasts. Indeed, the distinction between yeasts and bacteria is based upon this method of multiplication. The method of multiplication in bacteria is known as **fission**, and this group of fungi are called **fission fungi** in distinction from the yeasts, which are called **budding fungi**. The difference between these two classes can be distinguished only by careful microscopic study, but it is the scientific distinction between the two groups.

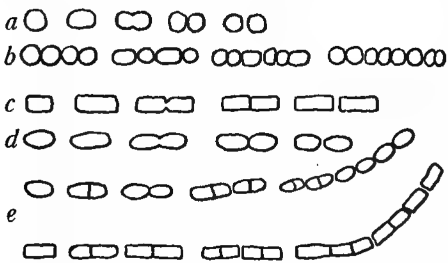


FIG. 52. Showing the method of multiplication by fission. *a*, a coccus form; *b*, a streptococcus; *c* and *d*, short rods; *e*, showing successive stages in the formation of chains, arising by fission from single cells.

Spore Formation. Under some circumstances bacteria have a different method of reproduction. Inside of the body of a single individual bacterium appears a little rounded mass which is known as a **spore** (Fig. 53). This spore may be broader than the rod which produced it, or it may be narrower; but it finally breaks out, the bacterium itself disappearing and the spore then coming out freely in the medium in which it lives. These spores are capable of subsequently germinating into new individuals like those that produced them and thus continuing the race (Fig. 53, *b*).

Not all bacteria produce spores, and the question whether any species of bacteria forms spores is a matter of most extreme significance in connection with its functions; for these spores are covered by a little shell which is hard and tough and capable of resisting various adverse conditions. Spore-bearing bacteria may be dried without injury, for their spores protect them from destruction. They may be heated to a high temperature, even to boiling, without being killed. Thus the presence of spores will make a great difference in the ease with which any material can be sterilized by heat. Bacteria not capable of producing spores are very easily killed by heat, while the spore-bearing forms are destroyed with much greater difficulty.

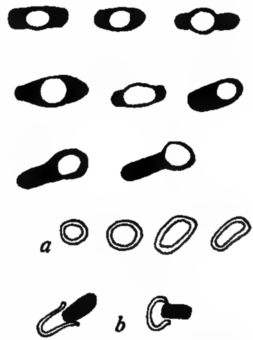


FIG. 53. Showing bacteria with spores. At *a* are free spores, and at *b* germinating spores.

GROWTH OF BACTERIA

Rapidity of Growth. The most striking fact in regard to bacteria is their wonderful rapidity of multiplication; for upon this are dependent their extraordinary powers. Bacteria growth and multiplication mean the same thing, and the rapidity with which they can multiply is almost inconceivable. Certain kinds of common bacteria can reproduce themselves once every half hour, the result of which is that a single bacterium will have become two in a half hour, four in an hour, eight in an hour and a half, and so on. This increase of progeny by geometrical progression results in the production of descendants with immense rapidity. If the rate of multiplying above mentioned should continue for twelve hours, the result would be the production of about seventeen million offspring. Such a rapid production as this does not continue very long, through lack of food and other adverse conditions. If it did, the world would soon become filled with bacteria, crowding everything else out of existence.

Recognizing that they have this wonderful power of multiplication, we can readily see that bacteria represent a force in nature of almost inconceivable magnitude. This rate of growth is a possibility for a while at least, and in order that such a multiplication should continue it is only necessary that the bacteria should be given proper food and proper conditions. The results are marvelous. Although they are so small that a single one can accomplish practically nothing in nature, the fact that this single one can in twenty-four hours produce millions of descendants gives to bacteria almost unlimited power. An appreciation of this fact is fundamental to an understanding of the action of bacteria. Since one in the course of a few hours may become hundreds of thousands, and a little later its progeny may be millions, it is clear that in order to protect any material from the action of bacteria something more is necessary than simply to *reduce* the number of microörganisms. If the material is to be protected from them, every single bacterium must be destroyed, for if but one be left alive it may require only a few hours for its descendants to become so numerous as to be able to accomplish almost anything in the way of chemical destruction.

Relation of Growth to Temperature. This great power of growth is dependent upon many factors, most prominent among which is temperature. Like all living things, bacteria will not grow at the temperature of freezing or below, but will develop at nearly all temperatures above, some species even growing at 140.° Certain species grow best at a temperature that is not much above freezing; others grow best at higher temperatures. Most of the common household types require considerable warmth for their proper growth, and the warmer the temperature, up to a certain limit, the more rapid their growth. The relation of temperature to the rapidity of multiplication, for common species, is shown by the accompanying figure (Fig. 54). At *a* is represented a single bacterium; at *b* is the progeny of this bacterium when kept twenty-four hours at a temperature of 50°, a little above that of the ordinary ice chest; at *c* is the progeny of this bacterium kept the same time at 70°, the ordinary temperature of a living room. A glance at the figure will show what an extraordinary influence a few

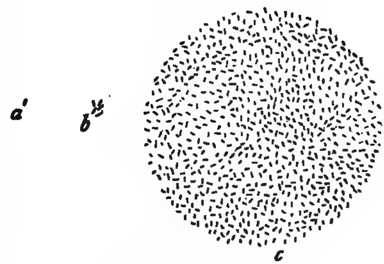


FIG. 54. Showing the effect of variations in temperature on bacteria growth. *a*, a single bacterium; *b*, its progeny in twenty-four hours at 50°; *c*, its progeny in twenty-four hours at 70°.

degrees of temperature may have upon the rate of growth of this bacterium. The figure teaches a very practical lesson in regard to the influence of cold in delaying the growth of bacteria and thus protecting food from spoiling.

If the temperature is raised too high, it has an injurious action upon the growth of bacteria. Each species of bacteria grows best at a certain temperature, growing less rapidly if warmed above this point or cooled below it. Most, though not all, of the bacteria against which the housewife has to contend grow best at temperatures between 70° and 95°. If the temperature is raised above 95°, many cease to grow so rapidly, and at still higher temperatures — between 125° and 140° — a large majority are quite incapable of growing at all. At the higher temperatures food would hardly decay. There are, however, a few species which grow only at very high temperatures, not developing at all unless it is above 125°.

It is perfectly evident that all problems connected with the protection of food from the action of microörganisms will be dependent upon the temperature at which the bacteria grow most rapidly. Food which is kept in an ice chest, although it may be protected from the action of those bacteria which grow only at room temperatures, will be exposed to other species that grow best at lower temperatures. When we remember that some kinds of bacteria grow at temperatures close to freezing, we can readily see that no method of cooling food short of actually freezing it will totally protect it from decay.

Death Temperatures. All bacteria are killed by excessive heat, but the temperature which kills them is somewhat variable. Bacteria exist, as we have seen, in two forms. One is the active, growing form, in which they feed and multiply rapidly; the other is the spore form, in which they are at rest, neither feeding nor growing. In the former condition they are easily killed by moderate heat, a temperature of 140° to 160°, if continued an hour (usually a much shorter time), being ordinarily sufficient to destroy them. In the form of spores, however, such a temperature has little value in destroying them. Bacteria can resist without being killed a higher temperature than can any other known form of living matter. Spores of certain bacteria can be boiled for a long time without being killed, and if subsequently cooled they will grow and multiply. To destroy the vitality of such spores requires a temperature above that of boiling water, a temperature rather difficult to obtain, at least for liquids, in an ordinary kitchen. It is, however, important to remember that although many kinds of bacteria spores are not killed by a *short* boiling, a boiling of a few hours is sufficient to destroy all but the most resistant spores. Any material, therefore, that can be boiled for a considerable length of time may ordinarily be thus **sterilized**, that is, may have its actively growing bacteria and their spores destroyed at the same time. This great resistance to heat on the part of bacterial spores is a matter of much importance to the housewife, and she should fully realize it. Canning processes, as we shall see, depend upon the destruction of bacteria, and the resistance of spores to boiling is a factor that should always be remembered.

A practical lesson to be drawn from these facts is that food heated to *boiling* in its preparation is thereby, in a measure, protected from spoiling, since the bacteria are mostly killed. But if the food is simply *warmed*, the spoiling is hastened instead of delayed. For example, in making beef tea, if the liquid is boiled, it will keep easily; but since boiling precipitates the proteids and deprives the material of most of its food value, it is better to make it by warming without boiling. Such material decays very rapidly, and, if set on the back of the stove to keep warm, will be spoiled in a short time. Moderate heat hastens bacteria growth. Boiling kills all but spores.

Light. Direct sunlight rapidly kills bacteria (except some spores) and daylight in general has an injurious effect upon them in proportion to its intensity. They grow best in darkness. Dust or dirt exposed to sunlight soon loses most of its living bacteria, while in dark cellars, dark corners, and cracks they may remain alive a long time. Hence the rooms in our houses should be kept light. The once common habit of closing blinds and using heavy curtains or shutters to keep out the light was a great mistake. Pantries and kitchens should have all the light possible. A sick room particularly should have all possible sunlight; and bright colors for wall paper, curtains, etc., will aid not only in making it cheerful but in actually destroying the disease bacteria. Sunlight and fresh air should everywhere take the place of the darkened, closed rooms which were too common in our houses in former years.

Relation to Air. Most living things require oxygen and therefore demand air for their growth. This is true of a majority of bacteria. Most bacteria like to feed where they can have plenty of air. Hence decay is apt to begin on the surface of things, extending towards the interior. This is not true, however, of all bacteria. Some species can grow perfectly well without air, and others, indeed, cannot grow at all if they are in contact with air. The latter bacteria, which live without oxygen, are known as *anaërobic;* the former, which demand oxygen, are called *aërobic.* The aërobic bacteria are by far the most important in the affairs of the household, but the anaërobic bacteria, on the other hand, produce certain types of putrefaction which are sometimes more serious, inasmuch as the products of putrefaction which take place without air are likely to be more poisonous than those products of decay taking place in contact with the air. We must remember, then, that whereas most bacteria grow best in the air, we cannot protect any material from the growth of microörganisms simply by keeping air away from it, inasmuch as some species grow perfectly well, and even better, out of contact with the air. Hence, in ordinary canning it is not the exclusion of air that makes preservation of food possible, but the exclusion of bacteria.

Moisture. Like yeast and molds, bacteria require water. Dry food is protected from their action because they cannot obtain water sufficient for their life processes. Bacteria, in general, require more water than molds. Various materials, if simply damp, will mold or mildew, but they will not support bacteria life unless the amount of water is considerable, 25% to 30% of water being necessary for much growth, and a still larger amount for vigorous growth. Hence they may be expected to grow in all kinds of food which are thoroughly wet, but they will not grow in any of the dried forms of food which we keep in our houses, a fact of much importance in connection with the problem of food preservation.

Acidity. For still another reason molds and bacteria do not commonly flourish upon the same material. The former, as we have seen, grow best upon acid substances; but most bacteria cannot endure acids, preferring a slightly alkaline food. Hence fruits, which are acid, decay by molding, while meats, which are not so acid or are alkaline, decay by bacterial action. The presence of acid or sourness in food will check its decay. Some food (cranberries) may be actually too sour for bacteria growth.

Where Bacteria may be found

We may almost say they are to be found everywhere upon the surface of the earth. This is not strictly true, since a few places seem to be free from them; for example, the middle of deserts and the bottom of the deep oceans. But wherever on the surface of the earth animals or plants are found, there, in the earth, the air, and all bodies of water, are also found bacteria.

Air. Bacteria are so extremely minute that they are capable of floating in the air for a long time and of being blown by the winds almost indefinitely. Consequently it is almost impossible, at least in inhabited localities, to find any air that does not contain them. The number that may be present in the air varies with the density of human population. We find them more abundant in city than in country air; more abundant, as a rule, in houses than out of doors; more abundant in the air of rooms well filled with people than in empty rooms, since they arise from clothes and skin. In the air of schoolrooms or audience rooms the number of bacteria is large, and there are more at the close of a school session than at the beginning. There are more bacteria in the air of a poorly ventilated schoolroom than in the air of a sewer. The presence of animals as well as of men always increases the number of bacteria in the air. Wherever we find dust, there we find bacteria. By this it is not meant that dust is composed wholly of bacteria, for many other things go to constitute what we know as dust; but among the dust particles we may be sure to find bacteria in great numbers. In short, all air in the vicinity of habitation contains bacteria. The air of high mountains far from the habitation of animals is found to be moderately free from these ubiquitous organisms. Elsewhere they are present in abundance. Since this is the case it is quite impossible for any material exposed to the air for even a short time to escape a rapid contamination with micro√∂rganisms.

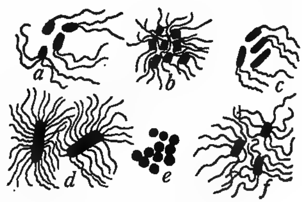


FIG. 55. A group of bacteria from water.

a, Pseudomonas fluorescens; b, Bacillus prodigiosus; c, Pseudomonas janthinus; d, Proteus vulgaris; e, Micrococcus aquatilis; f, Bacillus coli.

Water. Practically all bodies of water on the surface of the earth are filled with bacteria (Fig. 55). The number found in water, however, is widely variable. In *spring* water which comes fresh from the ground the number is small, and in some cases they may be wholly absent. The same thing is true of the water of *artesian* *wells*, drawn from a depth of a hundred feet or more. All surface waters are sure to contain them, for they are present in lakes, ponds, pools, rivers, and in the ocean. They are more abundant in flowing streams than in water standing in lakes or reservoirs, quite contrary to the usual belief. We commonly look upon running waters as purer than standing waters, but so far as concerns bacteria the reverse is usually the case. Rivers or brooks contain them in large numbers; lakes in which the water has stood for a long time contain a smaller quantity. The reason is that rivers and brooks collect the bacteria from the surface of the ground, from sewage, etc., and the longer they flow the greater the number of bacteria they contain, since they are great draining agents for the country. When water stands in lakes or ponds the bacteria, which are slightly heavier than the water, have a chance to settle to the bottom. This they do in the course of a few days, and after a time the water in such standing reservoirs becomes far purer than in the supply streams. It will easily be understood that the greater the amount of decaying matter entering any stream the larger will be the number of bacteria in its waters. The rivers of civilized countries, that receive the sewage from cities, not only contain these little organisms in immense numbers, but contain some of the most dangerous kinds, since they are the disease germs discharged from human patients.

From these general facts we reach the conclusion that no water at our command upon the surface of the earth is absolutely free from bacteria. Spring water is the purest, and water from deep artesian wells is about equally pure. Water from lakes and reservoirs is the next in purity, and water derived directly from flowing streams and rivers is most likely to contain these organisms in greatest numbers. The most dangerous water for drinking purposes is that of rivers which have been contaminated in any way by sewage material, a condition of things true of the water used in some cities.

Soil. Soil on the surface of the earth is usually filled with bacteria (Fig. 56). They are usually abundant in the superficial layers, decreasing rapidly as we pass below the surface, until at the depth of a comparatively few feet they practically disappear. They are more abundant in some kinds of soil than in others. Where the soil is dry and sandy the number is comparatively small; where it is moist and loamy they are more abundant. They are found profusely around buried bodies of animals, or in soil that contains decaying roots of ordinary plants. They are immensely numerous in the vicinity of earth closets or privies, and the soil near sink drains and manure heaps is filled with them. Indeed, any soil which contains the remains of animal or vegetable matter and a considerable amount of moisture will have bacteria in inconceivable numbers, while in cleaner soils they will be much less abundant.

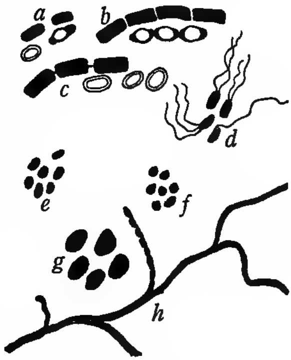


FIG. 56. Soil organisms.

a, Bacillus subtilis; b, B. cereus; c, B. megatherium; d, Pseudomonas fluorescens; e, nitrate organism; *f,* nitrite organism; *g, Azotobacter; h,* an *Actinomyces*

They are sure to be abundant in all dirt which accumulates in a household, for nearly all such dirt contains organic material in a state of partial decay. Any dirt which collects in corners of rooms, in the cracks of floors, or upon shelves in pantries, cellars, etc., is sure to contain bacteria in great quantities. The dirt that clings to the walls and ceilings of rooms is also quite sure to contain

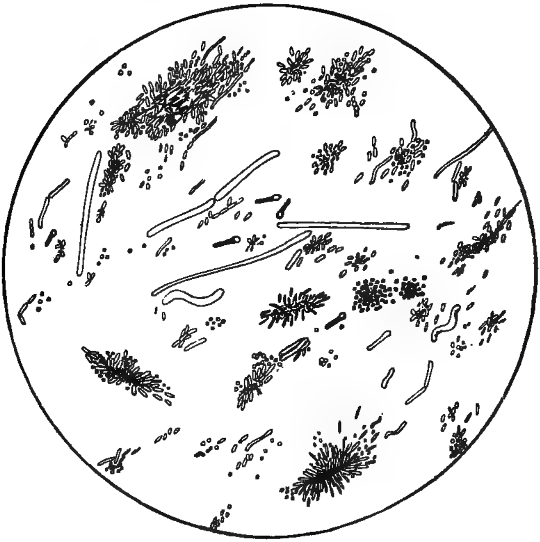


FIG. 57. A bit of decaying meat highly magnified, showing the bacteria feeding upon the material.

them, and the dirt collected by sweeping the floors is filled with them.

Bacteria in Food. Bacteria are found in all moist foods, especially in those undergoing the process commonly spoken of as spoiling (Fig. 57). Indeed it is the bacteria, as we shall presently see, that ordinarily cause this spoiling. Any meat which develops the *gamy* flavor is filled with them; *sour milk* contains them in immense numbers; *moldy bread* and *bad eggs* hold millions of them, and *decaying fruit* may show bacteria as well as molds. All types of food which develop peculiar taints and tastes characteristic of putrefaction contain great numbers of bacteria. Long before these taints are appreciable to the senses the bacteria that produce them are abundant. No moist food can be exposed on pantry shelves or in ice chests, even for an hour, without containing bacteria, and after it has remained there for a day or two the number of bacteria present in it may become very great indeed, because of the multiplication of those that have found entrance.

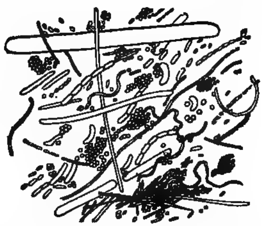
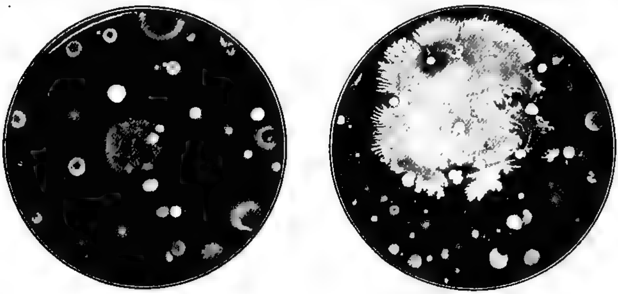


FIG. 58. Bacteria from the teeth of a healthy mouth.

In the Body. The presence of bacteria in food leads us to expect to find them in our mouths, stomachs, and intestines. Our whole digestive tract is crowded with them. Fig. 58 represents a bit of the scrapings from the teeth, highly magnified, and containing hundreds of several different species of bacteria. They are equally or more abundant in the stomach and intestines. This is the normal condition of things, and these bacteria do us no injury, but are probably of direct use.

Can we escape from Bacteria? Bacteria, in short, are practically everywhere on the surface of the earth. They are in immense numbers in the household, on the walls and ceilings of our rooms, upon our pantry shelves; they are present in every bit of food which remains exposed to the air for a short time; they are in all liquid foods, particularly milk. So ubiquitous are they that it is an absolute impossibility for the housewife, by any means at her command, to keep her pantry and food free from them.

These facts forcibly emphasize the futility of the common method of sweeping and dusting rooms. Bacteria are heavier than the air and, if undisturbed, settle and lie quietly upon floors, tables, etc. Every sweeping the room receives stirs them up. A dustbrush sends them flying through the room, only to settle down again later. On the other hand, wiping



a b

FIG. 59. Petri dishes exposed, one, *a*, before, and the other, *b*, after a class has occupied a schoolroom.

with damp cloths removes the bacteria and this is a proper method of cleaning. This is especially true for kitchens and pantries where food is exposed to the air, and for schoolrooms where there is likely to be a collection of numerous kinds of bacteria, including some disease germs brought by the many children. Fig. 59 shows two plates, one exposed to the air before and the other after a school session. The relative abundance of bacteria floating in the air is clearly shown. These facts forcibly show the advantage of vacuum cleaners, which remove the dirt without stirring up the dust.

These facts, too, show the desirability of having the walls of kitchens and pantries smooth and glazed, in order that they may not furnish lodging places for air bacteria and may be cleaned readily with a damp cloth. They also show us that lace curtains and heavy hangings around rooms will be lurking places for numerous organisms. This may do no harm in ordinary parlors, rooms where the bacteria are mostly harmless and where no food is kept, but should never be allowed in kitchens, and should be most emphatically forbidden in sick rooms where disease germs are likely to be floating about in the air.

The Results of Bacteria Growth

The bacteria with which we are concerned all require complex foods. Some species can live upon simple minerals from the soil, but these are of no importance in the household. All that are of interest for our purposes feed upon substances quite similar, in general, to those upon which animals subsist. Any materials containing *sugars*, *starches*, *proteids* (albumen, lean meat, etc.), or other animal foods, furnish excellent nourishment for bacteria. For this reason the bacteria are in a sense the rivals of the animal kingdom. Both animals and bacteria feed upon the same kind of food, and both are, therefore, constantly seeking to obtain and use it for their own purposes.

When we bear in mind the facts thus far outlined we can easily understand why bacteria play such an important part in the affairs of everyday life. They are too small to see, but are capable of inconceivably rapid multiplication. They are all about us in great numbers, in earth, air, and water. Some can be dried without injury, others frozen for months without losing their vitality, and even a short boiling fails to kill many species. With all these wonderful properties it is not strange that they are constantly at work all around us modifying the nature of all substances upon which they feed.

Parasites and Saprophytes

The food upon which bacteria feed may be either living or dead. If bacteria are capable of feeding upon the living body of an animal or plant, we call them **parasites.** Such bacteria quite naturally produce injury to the life of the individual upon which they feed. In mankind they produce a great variety of abnormal results which we call *diseases*. The parasitic bacteria, therefore, are commonly called **disease germs**, and are the cause of most of our contagious diseases. Many of them feed upon animals, producing animal diseases, while others live upon plants, giving rise to diseases in the plant world.

Fortunately only a comparatively small number of species of bacteria are capable of existing upon living bodies of animals. The great majority are incapable of feeding upon living tissue, although they feed upon it readily enough after it is dead. Those dependent upon the dead bodies of animals or plants cannot live a parasitic life. When bacteria feed upon such nonliving materials we call them **saprophytes.** They are, like animals in general, dependent for sustenance upon dead animal and vegetable food The saprophytic bacteria, while they may be rivals of animals for food, are not the cause of diseases. These harmless bacteria far outnumber the disease germs. We should not therefore be frightened when we learn that bacteria are all around us, in the food we eat, the water we drink, and the air we breathe. Most of them are harmless or beneficial, and need cause us no uneasiness.

It should also be noted, finally, that some bacteria can live both upon living tissues, like parasites, and upon dead material, like saprophytes. Such microörganisms are partly parasitic and hence are capable of producing disease. They are also capable of living outside the body in various localities in nature. They may be of serious importance to the health of man, inasmuch as they are capable of living a parasitic life if they can get into the living body; but are also able to live an independent life in nature. All disease bacteria either belong to this class or are strict parasites, while the harmless bacteria belong to the class of saprophytes.

CHAPTER XI

BACTERIA WHICH LIVE UPON DEAD FOOD: SAPROPHYTES

These include the bacteria found living freely in nature, in the air, in water, and in the soil. Since they live upon dead organic material they may be expected in any kind of food upon which the human being lives, as well as in other substances that do not serve us as food.

Materials that serve Bacteria as Food

Some kinds of food are very readily attacked by bacteria, others with more difficulty, and some hardly at all. Pure *sugars* are, as a rule, not attacked by them, although if the sugar is in water solution certain bacteria may sometimes feed upon it, and raw sugar is sometimes injured by bacterial growth. The same is true of pure *starches*, since most bacteria are quite incapable of making use ot pure starch. It happens, however, that nearly all of our food materials containing starch and sugar contain also other substances upon which bacteria can feed, so that the sugary and starchy foods in our households are by no means exempt from them. *Fats* are also attacked by bacteria, although less readily than some foods. By bacterial action the fat is made rancid and undergoes other less familiar changes.

The food most readily attacked by the majority of bacteria is the class known as *proteids*. Proteid materials are foods for nearly all species of bacteria, are most easily attacked by them, and are sure to be consumed if exposed to the air under proper conditions. By proteid food is meant a class of chemical substances, highly complex in nature, which may best be understood by illustrations. The best known examples are the following: the white of egg, named *albumen;* the lean part of meat, known by chemists as *myosin;* the curd of milk, called *casein; gluten*, which is the gummy substance present in wheat flour; a similar substance present in beans, known as *legumen*. All of these substances will be recognized as liable to putrefy rapidly. Nearly all of our foods contain either these proteids or others in greater or less abundance. Anything made of flour contains gluten; anything that has milk in it contains casein; all meats contain myosin; anything made of beans or peas contains the legumen, while eggs always furnish albumen. Since most foods contain some of these substances, and since cooking does not change their nature, practically all foods hold some of these proteids.

Proteids are of all foods the most necessary for the human body. While the body might live on proteids alone, it could not live entirely on any other kind of food, and proteids therefore are absolutely necessary for the human body. Most bacteria flourish upon proteids as well as we do, and inasmuch as practically all of our food products contain a certain quantity of proteids, it follows that nearly all of our foods are readily consumed by the great host of saprophytic bacteria.

The Effect of Bacterial Growth upon Food

If any common food product is sufficiently moist, bacteria which get into it from some source are sure to grow and in the course of a few hours will produce marked changes therein. But bacteria do not consume food as large animals do by taking it bodily inside of themselves. They are quite too small to do this. To the eye it does not seem that the bacteria are actually consuming the food but that they are simply producing noticeable changes within it. In reality, however, they are consuming it and in the end cause its almost complete disappearance. The essential effect that they produce is the chemical decomposition of the material upon which they are feeding. Bacteria do not consume the whole food but use only a part of it. An illustration may make clear their mode of action. If a house is built with a wooden frame and brick walls, and the wood is burned away, the house is sure to tumble to pieces, because the wooden framework is necessary to hold the building together. Much the same thing is true of a chemical molecule, which is a structure made of a variety of substances bound together to form a unit. Bacteria, as they utilize foods, have the power of taking some of these materials out of the molecule, but cannot consume the whole. The result of extracting some of the material from a molecule is that the entire structure will fall to pieces, just as the house falls whose framework has been burned away. The meat becomes putrid, the milk sours, the egg rots, and any other material containing proteid undergoes a similar type of spoiling.

New Products

Decomposition Products. When a house falls to pieces after burning, a mass of débris is left lying in the old cellar. So, when the chemical molecule is broken to pieces, as described above, there will remain certain fragments of the original molecule. Although really fragments of the original substances they are quite different in nature from the original material. They are known as by-products of decomposition, or simply as **decomposition products.** Whenever bacteria grow in a mass of food, destroying the chemical nature of the food molecules, there is sure to be produced a variety of materials representing the débris from the destruction of the molecule. These materials are by-products of decomposition and are always of a nature quite different from the original food substance. They are, as a rule, simpler in their chemical nature than the original food, and are quite different in their physical characters.

From the original food, which may have been a partly solid material, like a bit of meat, there arises as the result of its destruction a number of these by-products, some of which are in the form of gases and pass off into the air, some of which are more or less liquid and remain behind in the food mass. Others are easily soluble in water and dissolve in the liquids of the food. Thus the food material is almost sure to soften gradually and to become of a more or less fluid nature. There is likely to be a considerable variety of these by-products, some of them having new odors and tastes. The new materials give to the food mass as it is consumed by bacteria wholly new flavors;

and since some of them are vapors they may give it a strong odor. Consequently the food material which is being consumed by bacteria soon begins to have a very strong taste and odor, due to some of these decomposition products. The character of the food changes very greatly, and after the bacteria have had an opportunity of feeding upon the material for a comparatively few hours no resemblance to the original food mass remains, in appearance, taste, or smell.

This whole phenomenon is spoken of as **putrefaction,** or **decay.** There is, however, a slight difference between these two terms. By putrefaction we commonly mean a change in food masses by which a series of very unpleasant odors and tastes make their appearance in the putrefying mass. By the term "decay" we properly mean a more complete destruction of the food material, in which the unpleasant odors and flavors finally disappear, leaving behind a comparatively odorless material which represents the final débris remaining from the total destruction of the food masses. Putrefaction, with its high flavors and odors, is an incomplete process; decay, a more complete process of destruction. Putrefaction is produced in general by bacteria when they do not have an abundance of air or oxygen, whereas decay occurs when the amount of air or oxygen present is abundant. In other words, when a bit of food is being consumed by bacteria without sufficient oxygen it putrefies and becomes offensive in taste and smell; when, however, the oxygen is abundant, the process of putrefaction goes on to a more complete destruction, ending finally in what is known as decay, by which the material is converted into inoffensive substances.

Bacterial Secretions. Besides the decomposition products just referred to, another class of new substances is found in the putrefying and decaying food, and these are to be regarded as **secretions** from the bacteria. Bacteria are living organisms and, like larger animals and plants, are constantly emitting from their bodies certain secretions. Our own bodies are constantly secreting materials, like perspiration, urea, etc.; and bacteria, as the result of their activity, are also constantly producing a small amount of secretions. These secretions are totally different products from the original food. The secretions from some species of bacteria are quite harmless, although others are of an intensely poisonous nature. As a result, a bit of food that is undergoing putrefaction may in the course of time become highly poisonous because of the appearance of poisonous materials, part of which may be decomposition products but most of which are probably bacterial secretions.

Chemists and bacteriologists are not able to separate very clearly decomposition products from the secretions of bacteria, and for our purpose it is quite unnecessary. We need only remember that as the bacteria consume our food products they produce profound chemical changes which we call putrefaction and decay. As the result of these changes not only is a host of highly flavored products developed but also another series with strong odors. Some of these new products are poisonous, others are not. All of them have a tendency to be softer than the original food and more easily dissolved in water; the result of which is that as the food is consumed by the bacteria it becomes softer and more liquid. In the end it largely disappears, being dissolved into gases which pass off into the air and liquids that soak down into the soil or evaporate, leaving only a small residue. This is the general phenomenon of putrefaction, ending in complete decay.

Advantages from Incipient Decay. Although this process of decay may be a somewhat rapid one, it actually takes place by steps, one after another. The breaking down of the food under the action of bacteria is not a sudden falling of the molecules into fragments but a process that takes considerable time and presents a number of intermediate steps between the original food and the final condition of decay. As the bacteria begin to act upon the food it is not at first necessarily ruined or even injured. At the beginning of the process the new products are quite different from those that appear later, and it may happen that those first produced give to the food a slight *flavor* which, instead of injuring its character, actually improves it.

The presence of a certain amount of flavor in our foods is very desirable, and even necessary. Pure foods without flavors cannot be properly digested and absorbed, a certain amount of flavor being needed to stimulate the digestive organs. Some of the flavors arising in the early stage of decomposition are of a character that is enjoyed by the human palate. For example, the so-called *gamy* taste of meat is a flavor which some people enjoy very much, while others dislike it. This gamy taste is simply the beginning of decomposition, and is due to the fact that the meats have been kept until the bacteria have begun to act upon them and to produce the incipient stages of putrefaction. In this early period the flavors are not very strong and not particularly unpleasant; but if the process is allowed to go a little farther the taste of putrefaction becomes too strong for any palate. Another example is Limburger cheese, in which a strong flavor of incipient putrefaction is produced by the development of bacteria in the cheese mass. Any one who has ever known the flavor or taste of Limburger cheese will easily believe that it is incipient putrefaction. Other forms of soft cheeses show the same feature in less degree. A great variety of flavors and odors is found in the so-called soft cheeses, nearly every one of which represents a certain type of incipient putrefaction. Even the hard cheeses show this same characteristic, though there is less similarity to putrefaction. Nevertheless the taste of the hard cheese is probably, at least in part, due to the beginning of this process of chemical destruction produced by bacteria. If the cheese has become overripened, a very strong decayed taste may be apparent. In the making of butter the same phenomenon occurs, for the extremely delicate flavor of a high quality of butter is due to the action of bacteria upon the cream before the butter is made, and the butter flavor is thus one of incipient decay (Fig. 60). It is one of the most exquisitely delicate of all our food flavors, and is highly enjoyed by all people.

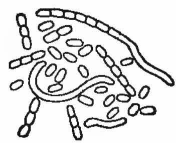


FIG. 60. Bacterium producing good flavors in butter.

VINEGAR

Another example of a benefit derived from bacterial action is in the manufacture of vinegar. This is a material which, though not a real food, is used in considerable quantities as a condiment and preservative. As ordinarily made it is simply a product of bacterial growth. The basis of vinegar is *acetic acid*, and this is produced from alcohol by certain changes brought about in it through the action of microörganisms. The source of vinegar is always some weak alcoholic solution, commonly cider or weak wine; but any liquid that contains a moderate quantity of alcohol may be a source of vinegar. This material is caused to undergo a chemical change which converts the alcohol into acetic acid, and when this occurs it becomes vinegar.

The change of the alcohol into acetic acid is brought about by the presence of a material, a brownish, felted, slimy mass, which increases in amount as the vinegar is made, and upon whose presence the conversion of alcohol into vinegar seems to depend. This has long been known as **mother of vinegar.** Good vinegar will always contain such mother. The study of this mother of vinegar shows it to be a mass of bacteria (Fig. 61). They are crowded together in countless millions to form this slimy mass, and during the production of the vinegar multiply rapidly and finally become excessively numerous. The *growth* of the bacteria produces the change in the alcohol which converts it into acetic acid. The formation of common vinegar is therefore due to the development of microörganisms. Some types of a cheap product are made by a chemical process, but all good table vinegar is produced by bacteria.

A knowledge of the manufacture of vinegar is to-day a matter of little importance in the household, for the material is commonly made either in large factories or in a farmer's cellar. The housewife is simply concerned in purchasing a good product, and in its use. The type of vinegar commonly regarded as the best is that which is made from cider, although a large part of the vinegar used in the world is made from some other source of alcohol (wine, beer, etc.). The value of vinegar is in a measure dependent upon its flavor, which differs according to the material from which it is made. Vinegar, of course, has always an intensely sour taste from the presence of acetic acid, but in addition to this there are other flavors, due to the original material from which it is produced, and these affect its value. Vinegar also varies in color according to the substance from which it is made. Cider vinegar is of a rich brown color, while if made from other materials it may have a reddish or whitish color, or may be almost black. The color, therefore, is no indication of the character of the vinegar, for a perfectly good product may be white, red, or brown. The market value of vinegar is dependent chiefly upon the amount of acid it contains. The higher the percentage of acid (the sourer it is), other things being equal, the greater its value.

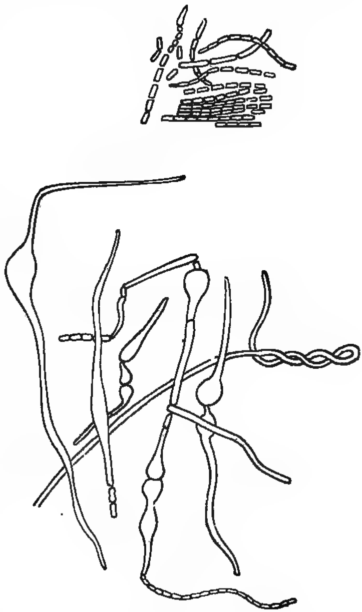


FIG. 61. Bacteria producing vinegar.

Although they are not bacteria a word may be said in regard to the *vinegar eels* frequently found in good cider vinegar. These are minute little *worms*, just visible to the naked eye, which are frequently seen swimming near the surface. Their presence may be consistent with a good quality of vinegar. They do not themselves have much influence upon vinegar, although if abundant they weaken its strength. They are quite harmless to the person using the vinegar, and one need never be suspicious or throw away any because it contains large numbers of these eels. They must be looked upon as present in ordinary good cider vinegar, and must be classed among the perfectly harmless organisms which are sure to occur in some of our food products.

Food eventually ruined by Bacteria

These illustrations are sufficient to show that the by-products of decomposition are not always necessarily disadvantageous to our foods. If the chemical destruction is only beginning, the result may be of a pleasant nature, and the food may be actually benefited by the action of the bacteria. If, however, this process is allowed to go farther, most foods are entirely ruined. Gamy food soon becomes putrescent; soft cheeses of all kinds soon undergo putrefaction and decay, and even the hard cheese in the end will become ruined by the development of too strong a flavor of putrefaction. Butter in the course of time is also ruined, although bacteria do not grow readily in butter and it may be kept a long time without undergoing putrefaction. It is, however, really impossible to draw any line between the incipient decomposition that benefits the flavor of food and the later stages which utterly destroy it.

Although the flavors of incipient decomposition may be pleasant and useful, the taste produced by later stages is offensive. In the end the food is always totally ruined, for bacteria will finally produce the complete destruction of the materials upon which they feed. The kinds of putrefaction, that is, the odors and tastes that develop, are by no means always the same. Different species of bacteria produce different results, and the same species of bacteria produces a quite different kind of decay in different sorts of food material. But it is a matter of little significance what type of putrefaction occurs, for all of them are equally sure to destroy the food. It is useful to remember, however, that the kind of decomposition which is produced when bacteria grow without sufficient air is always more unpleasant and more dangerous than that which takes place where there is plenty of air. Any food material which is closed in tight bottles or jars and undergoes putrefaction is sure to give rise to more unpleasant odors and tastes and to decidedly more unpleasant types of decomposition than food material which decays in the open air.

Garbage

All the refuse from our tables or our kitchens is just as good food for bacteria as is the material which we actually consume, and all of this waste material, after we have discarded it, is attacked by bacteria. This is shown simply enough by the odors arising from garbage if it is allowed to stand, the putrefaction and decay that set in being sure indications of the presence of bacteria and proofs that the bacteria are decomposing the material. Such waste material is, of course, of no use in the household, since it is not in a condition to attract the palate of man; but there is a large amount of food material left in these waste products which is very useful for feeding certain animals. It has commonly been used for feeding hens and hogs, and the recognition of its food value has in recent years made the garbage of our large cities a very valuable product. This use of garbage is being abandoned as unhealthful, and the practice of burning the material is becoming common.

The housewife is not, however, concerned in this problem but only in the proper disposal of the waste material from her kitchen and her table. This she simply desires to get rid of, and its tendency to rapid putrefaction makes it imperative that it be disposed of at once and not allowed to accumulate. She can adopt a variety of methods for this purpose. She may burn it, provided it is not too large in quantity, is not too moist, and she has a fire hot enough for the purpose. As a rule, however, burning garbage in an ordinary kitchen stove is not very feasible. Household incinerators specially designed for consuming moist garbage and similar material are now available. Where possible this is the best means of getting rid of the waste.

A common method of disposing of garbage in a city is to allow it to be removed by those who pay for the privilege because of the value of the material for feeding hogs. The household waste is placed in receptacles, which are emptied by the garbage collectors. In order that such receptacles may be kept in a tolerably wholesome condition, the garbage should be removed frequently, and for this we must depend upon the faithfulness of the collectors. The vessels themselves should occasionally be cleaned. If not cleaned, they give rise to unpleasant, unwholesome odors in or around the house. They may become the breeding places for flies and prove to be in general a considerable nuisance.

The chief trouble with such garbage cans is their smell and unsightliness, but these difficulties are removed if the cans are kept clean. It is not difficult to clean them. Cold water for washing garbage cans is of very little use; but if they are thoroughly washed with very hot water they can be kept so clean that they emit no odor and are not unpleasant. Since putrefaction is due to bacterial growth it is of course possible to prevent the smell and decay of the garbage by the use of disinfectants. Borax might be used for the purpose, but it is expensive; and the use of more vigorous disinfectants is likely to make the material poisonous to hogs subsequently fed upon it, or to dogs who very frequently feed upon the contents of the garbage receptacle. Such disinfectants are quite unnecessary, and the only thing that the housewife needs to do is to keep the garbage can tolerably clean, and to see that it is emptied as frequently as possible. She should remember, however, that she cannot depend upon the garbage man to clean the receptacle. He will simply empty it. If the garbage can gets to smelling offensively, a thorough washing with hot water and sal soda applied vigorously with an old broom will make a great improvement. Naturally greater attention must be given to the matter in the summer than in the winter.

Closely associated with these problems are certain other minor questions relating to the kitchen sink. In the ordinary sink a considerable amount of organic material is liable to find its way into the drain and trap. The cloths used for washing dishes are also quite sure to become soiled with various forms of organic material from the food. These materials are liable to bacterial action and therefore will decay and become offensive. Consequently boiling water should be occasionally poured down the sink drain to disinfect the trap as far as possible, and the cloths used in dishwashing should be thoroughly washed in boiling water and dried to prevent them from becoming offensive by furnishing a chance for bacterial growth.

CHAPTER XII

THE PRESERVATION OF FOOD: DRYING; COOLING

The growth of bacteria in food is nearly always undesirable and the housewife must always aim to prevent it. Even where the incipient decomposition products are useful because pleasant to taste, this taste is developed in the food before it is received into the house, so that the housewife is not concerned in the methods adopted to produce the flavors. Her sole aim must be to prevent the food from spoiling. To do this she must constantly bear in mind that putrefaction is always due to the growth of microörganisms, and that all types of putrefaction and decay may be prevented by stopping the growth of such organisms, and delayed by decreasing its rapidity. Anything which will check the activity of bacterial growth will delay the spoiling of food products. In order to know how to treat food for this purpose it is most useful to bear in mind the facts already mentioned in regard to the growth of bacteria.

To the housewife of to-day the problem of food preservation is of less significance than it was formerly. To-day, at least in all communities of even moderate size, these problems have been largely solved for her by the marketman, and she can buy her food in such small quantities that frequently she does not need to consider the problem of preservation. The housekeeper of earlier days was confronted with many problems in the home preservation of meats, vegetables, and fruits, because she was likely to have large quantities brought to her hands at once for immediate disposal. But though the questions are not so pressing in the modern home, they are still constantly arising in the well-regulated house. A somewhat extended notice of the subject is therefore necessary.

The Use of Foods while Fresh. The first thing that must always be borne in mind is that nearly all kinds of food are better when used as fresh as possible. The sooner food is consumed after it reaches the household, the surer it is to be free from the troublesome action of bacteria, and the more certain it is not to develop decomposition tastes and flavors. The necessity of using food while fresh is much more imperative with some foods than with others. Meats and milk are especially liable to spoil, — the meat of immature animals more quickly than that of adult animals, — and must be used promptly. Many fruits, like cherries, berries, peaches, and pears, keep only a short time, and beans and peas spoil very quickly if kept moist. The endeavor should always be to use such materials at once.

The housewife in our modern community should remember that only a small proportion of the food she buys is really fresh. The crowding of people together into cities demands a food supply coming from long distances, and the constantly open markets twelve months in the year require some food to be preserved for weeks and months before use. Hence our city markets are filled and our tables loaded with various forms of preserved foods; and whether she buys canned or salted goods, or meats or poultry, the housewife may be confident that some device for preservation has likely been used in their preparation. The modern city is possible only because we have learned methods of food preservation.

It is of course not always possible to use all kinds of food in a fresh condition, and it becomes quite necessary to have some means devised for their preservation. The means adopted for preservation are always to subject the food to conditions unfavorable for bacteria growth.

Drying

Since bacteria require a considerable quantity of water for their growth and multiplication, they will not develop at all in foods that are even moderately dry. Molds will grow upon a food that has only a small amount of water, but bacteria require from 25% to 30% of water in their foods in order that they may grow. Molds will grow upon damp floors, damp cloth, or paper, but bacteria can attack these materials only when soaked with water.

A practical application of this fact is *drying*, — one of the most widely used methods of preserving food. This is adopted by nature for the purpose of preserving many food products, like corn, wheat, oats, rye, etc. Nature wants to keep such seeds from decaying for some time, perhaps during the winter season, in order that they may be in good condition for the growth of the young seedlings in the spring. To accomplish this the seed, when it ripens, is deprived of its moisture, so that when fully ripe and ready to be shed from the plant it has become a dry, hard, tough mass, forming the grain of wheat or corn, or the dry pea or bean. Such a food material is beyond the reach of bacterial action, and, unless these grains become subsequently soaked with water, they are protected from decay (Fig. 62). Bacteria grow in them readily enough in the spring when they are moistened and begin to sprout.

This drying of the grains protects all kinds of flours and meals made from them. The wheat is ground into flour, and the corn into meal, each of which contains but a small amount of moisture, far too little to allow bacteria to feed upon the material. Flour is perfectly good food for bacteria, and if we only moisten it with water, putrefaction and decay begin in a short time; but as it is ordinarily prepared the amount of moisture is too slight for bacteria. The same is true of all flours or meals prepared by grinding dried seeds furnished by plants. To a less extent the same is true of various food preparations made from these flours. In making bread or cake dried flour is mixed with water and subsequently baked. The mixing of the flour with water brings it into a condition for bacterial action, but the baking dries up enough of the water to preserve it. If the baking is so thorough that the water is almost completely driven off, as in the case of *dried biscuits*, or *crackers* as they are called in the United States, the

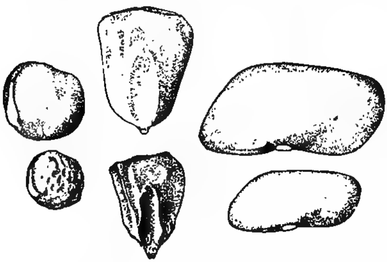


FIG. 62. Showing nature's method of preserving seeds by drying. The upper figures are the fresh seed, the lower figures the same after drying for winter preservation.

material is left so completely dry that bacteria cannot consume it at all. Dried crackers, if kept dry, can be preserved indefinitely, neither decaying nor molding. In the case of bread and soft cakes the water is not wholly driven off; hence these foods are not protected entirely from the action of microörganisms. As a rule bacteria cannot attack them and the housewife hardly fears their decay; but molds can grow upon them readily, and they must therefore be protected by means already suggested.

In addition to foods that are naturally dry, a large variety of others may be preserved completely from bacterial action by artificial drying. This method of preserving has been known for centuries and is understood by both civilized people and savages. Most kinds of *meat* can be treated in this way, and the drying of meat is carried on to a large extent in different parts of the world. The frontiersman and the hunter in the woods sometimes cut the flesh of deer, bears, and other animals into thin strips and hang it where it will be dried by the heat of the sun. This dried meat is called *pemmican,* a tough, hard, dry substance which can be kept for months without danger of decay. It is good food, though somewhat less digestible than fresh meat. A similar drying could be adopted in the household to preserve meats, but it is rarely worth while.

Usually the efficacy of the drying is increased by the use of salt. This plan for the preservation of meat is adopted in many parts of the world where cattle are plenty and the market is distant. In South America thousands of tons of dried flesh are prepared each year, the drying in this case being produced artificially, and the meat being still further protected from decay by the addition of a small quantity of salt. Such preserved meats are then shipped all over the world and form an excellent food which can be kept indefinitely. The commercial names under which this dried meat is sold are several; the more common ones are *charque* and *tassajo*. Such meats, though useful, do not take the place of the fresh product. Their flavor is changed; they are tough and not easy to digest.

A more familiar method of preserving meat is the curing of *hams*, *bacon*, etc. In such cases the flesh is first salted thoroughly by soaking in a brine, and then subjected to the action of smoke from burning wood. Such smoked food is thoroughly protected from bacterial action by at least three factors: (1) The material becomes somewhat dry, so that the bacteria cannot readily act upon it. (2) The action of the smoke is in a measure antiseptic, partly destroying bacterial life upon the surface, and at the same time so impregnating the meat with injurious volatile products that bacteria cannot ordinarily grow in it. (3) The salt is itself injurious to bacterial life. The ham is thus preserved from the action of bacteria by a combination of drying, smoking, and salting, all of which processes together are sufficient to prevent completely the subsequent growth of bacteria, although molds may grow upon it if it is not properly protected. The same thing is true of dried beef, a material preserved from decay partly by a preliminary soaking in brine and partly by a subsequent drying. The methods of preparing dried beef vary. Sometimes the process is one of artificial drying simply, but commonly smoking and salting are adopted to aid in the process. The drying of flesh is sometimes carried out so completely that the mass can be reduced to a powder. Powdered meat, however, is an article of commerce not very widely used.

Drying is adopted extensively for a variety of other animal foods. It is much used in preserving *fish*, sometimes without salting, sometimes with an abundance of salt. The heat of the sun, artificial heat, and smoking are all employed. *Mussels* and other *shellfish* are sometimes preserved by drying.

One of the most recent and most useful applications of drying is in evaporating *milk*. Skim milk is easily dried into a powder and will keep indefinitely without decaying, souring, or molding. It is one of the cheapest as well as most nutritious of foods. It does not quite take the place of fresh milk, for when dissolved in water most dried milks have a taste unlike milk. For baking, it is as good as fresh milk, and is most excellent for camping parties. Whole milk, when dried, does not keep so well, since the fat in it becomes rancid in time.

The drying of eggs to a powder form has been successfully accomplished, and in this form they may be used for all cooking purposes.

In the drying of flesh, milk, etc. it must be remembered that the process simply checks the growth of bacteria but does not necessarily kill them. Hence, if the milk contained any disease germs at the time of drying, the process itself would not remove the danger of eating it. Meat from diseased animals cannot, therefore, be rendered fit to eat by drying. Even the parasitic worm, *Trichina*, can withstand the smoking in the curing of ham. Unless the temperature is raised quite high during the drying, the process does not, therefore, remove dangers attending the use of food procured from diseased animals. In the process commonly adopted for drying milk, sufficient heat is used to render harmless any disease germs it may have originally possessed.

A large variety of *fruits*, *berries*, and *vegetables* are also capable of preservation indefinitely by the simple process of drying. The farmer's wife has long known that she can preserve apples by cutting them into small pieces and hanging them in strings over her kitchen fire to dry. The same thing is possible for many vegetables, like squashes, pumpkins, and even potatoes. Many kinds of berries — blackberries, blueberries, strawberries, and some others — can be preserved by merely extracting from them a large part of their water. This drying of fruits and vegetables is often accomplished by subjecting them to artificial heat, but more commonly in recent years the materials are subjected to hydraulic pressure, by means of which the water is actually squeezed out. A slight subsequent drying is then sufficient to preserve the material almost indefinitely.

Some fruits are preserved by a combination of drying and the presence of considerable sugar. *Raisins*, for example, are dried grapes, but they are not dried so completely as berries, for some moisture is left in them. The preservation of the raisin from decay is due in part to the lack of water, but chiefly to the presence of a high per cent of sugar, which is in itself deleterious to bacterial action. So, too, with other sweet fruits like *prunes*, *apricots*, *figs*, *dates*, *currants*, etc. Their preservation is partly a matter of drying and partly the result of the sugar present.

A large variety of fruits may be preserved by drying if we only have proper means for extracting the water. Indeed, probably any fruit could be thus preserved for future use if we could find a practical method of drying it. To do this the fruit, divided into small pieces, must be subjected to a heat sufficient to dry it rapidly so as to prevent decay, but not sufficient to cook it. It is hardly worth while to attempt such work in the ordinary home, for the results are not entirely satisfactory, and dried fruits are easily purchased. Some such method is practical with certain fruits and impractical with others; but it always greatly changes the nature of the fruit. Before it can be used the dried fruit must be soaked with water to soften it, after which it rarely bears much resemblance to the original fruit. Dried apples are quite different from fresh; the taste of the fresh apple has wholly disappeared, leaving in its place an entirely different flavor. The same is true of practically all fruits preserved by drying. Their mineral content has not been reduced, and this is one of the most valuable aspects of fruit in our diet. But most of us eat fruit for their flavors, rather than for the sake of their dietary value. Dried fruit is much inferior in taste and cannot be used for so many purposes as fresh fruit. The drying of fruits and vegetables often leaves a pulpy, somewhat tasteless substance, which has lost the peculiar charm which gives value to the fresh fruit.

It must be evident, then, that drying is the most widely adopted method of preserving foods, but it is not equally useful for all kinds. With some it works to perfection. For grains or other foods obtained from seeds it leaves nothing to be desired. It is useful for meats and many other kinds of animal foods. For vegetables and fruits its value is far less, and sometimes very doubtful. For them it should be used only where there is a large quantity of fresh material for which no better method of preservation can be found.

Use of Low Temperatures

The value of low temperatures in preserving all forms of food is familiar to every one. Microörganisms are stimulated into active growth by high temperatures and checked by low temperatures. It must be remembered, however, that the temperature at which bacteria grow most readily is not always the same; for although some species flourish only at warm temperatures, from 70° to 100°, others grow best at temperatures only a few degrees above freezing. While, then, a low temperature will check the development of most bacteria, it will not, unless it is actually below freezing, wholly prevent it, since some species grow readily enough at low temperatures. In the consideration of the use of low temperatures, therefore, three phases of the subject may be considered, based upon the degree of cold obtained.

1. **Cold Storage.** By cold storage is meant the use of storehouses which are cooled artificially, and where a very low and constant temperature is maintained for months at a time. In some compartments the temperature is held at a few degrees above freezing, while in others it is even below freezing. These low temperatures are commonly produced by the use of artificial-ice machines,

based upon the vaporization of ammonia, and kept constant in spite of great changes in the temperature of the air outside. Cold-storage plants are a modern device, and only within comparatively recent years have they come to be used to any considerable extent for the preservation of food. They are now found in all our large cities, and they are being utilized more and more each year, producing profound modifications of the conditions of civilized life. By means of them a large variety of foods can be preserved for many months without any tendency toward putrefaction and decay, and may be used at any time with the confidence that they have been kept in a perfectly good condition. The cold-storage plants make it possible to keep fresh for winter or spring use a large quantity of the perishable products which previously, if not capable of preservation by canning, it was necessary to throw away because of the certainty of putrefaction and decay. Such devices are being used more and more, and are producing a far more stable condition in the food supply. It is now possible to have fresh at any season of the year the perishable food products produced at almost any other season, provided we take the trouble to preserve them in cold-storage plants, and our city markets can furnish fresh fruits at almost any time.

The length of time during which food can be preserved by cold storage depends upon the temperature. If actually frozen, as is commonly the case with fish, fowl, and flesh, it makes little difference how long it is kept. Frozen food in the arctic regions keeps for years, and will indeed keep as long as it remains frozen. The same would be true of frozen food in cold storage. But some kinds of food, particularly fruits, are ruined by freezing under ordinary conditions. In these cases the temperature may approach freezing but must never quite reach it. Such food will be preserved for a while, perhaps for months if the temperature is low, but not indefinitely. It has recently been found that even fruit — or at least many kinds of fruit — can be kept frozen indefinitely if kept in a sirup containing the right amount of sugar. Another method of freezing, applicable to fruit as well as various other kinds of food, is a recently developed process known as quick freezing. In this process the food is frozen almost instantaneously by passing between two sheets of very cold metal. Such frozen fruits taste almost like fresh fruit, but must be consumed immediately after thawing, as they spoil rapidly.

The cold-storage plant cannot be utilized by the housewife, although temperatures nearly as low can be obtained in modern mechanical refrigerators. She should always remember, however, that during the winter and spring a considerable part of the perishable food products purchased in markets has come from cold-storage plants, where they have been retained for a long period at a temperature in the vicinity of freezing, or even below it. If she buys fish, fowl, or fruit during the winter, in a city market, she may regard it as probable that they have come from cold storage. This is a matter of considerable importance, because of the practical question of the keeping properties of such material.

It is a general belief that meats and other materials that have been frozen decay very rapidly after they are thawed out, and hence that food taken from cold storage must be used quickly, since it will putrefy more rapidly than when fresh. This is partly due to the fact that food just ready to spoil is placed in cold storage to preserve it. Such food will spoil at once when removed from the freezing temperature. Possibly, also, the food is slightly changed in its physical nature by the freezing, so that bacteria can more readily act upon it when it is thawed. In many cases, however, especially with fruits, which are not actually frozen, the rapid decay which follows removal from cold storage is due to the large amount of moisture which condenses upon the surface of the cold fruit when it is placed in warm or damp air. Such surface moisture, as we have seen, furnishes the necessary condition for the starting of mold growth. The practical lesson to be learned is that after the material has been removed from the cold storage and warmed up to ordinary room temperatures, it should be consumed as soon as possible, because putrefaction and decay are sure to take place speedily. If not used at once, it must be kept in an ice chest.

Properly controlled, cold-storage plants are of very great value to the public. The objections to them are chiefly two. They enable unscrupulous people to freeze food that is ready to spoil, and therefore not fit for eating, and subsequently to put it on the market. They also make it easier to gather great quantities of foods in the hands of a few persons, who, controlling so large a supply, can manipulate prices. Except for these misuses, which can be controlled by law, the cold-storage plant is a great boon to the consumer.

2. Mechanical Refrigeration in the Home. Of all household devices, the mechanical refrigerator gives the nearest approach to cold-storage conditions. Several types of these are now on the market, differing considerably in detail but alike in general principles. They all function through the condensation and vaporization of a gas, the cooling being effected by the drop in temperature produced upon vaporization. The condensation is generally brought about mechanically by means of an electrically driven pump, although in one type the object is secured by heating the gas at one point of the system by means of a flame and cooling it at another by means of water. Whatever principle is employed, the device enables the housekeeper to obtain much lower temperatures than by means of ice. Hence much more efficient refrigeration is available in the household today than was possible in former years.

In the mechanical refrigerator the temperature within the freezing coil is below freezing. That place is, therefore, not suitable for preserving many kinds of food; but is rather used for freezing water and desserts. A frozen dessert may, however, be preserved almost indefinitely if placed in a pan inside the freezing coil. Just below or just beside the coil, a temperature as low as 35° is easily obtained; in fact an electric refrigerator may easily be set so that freezing temperatures are secured just beneath it. Accordingly the space either below or beside the coil (depending on the model of refrigerator) is designed for storing very perishable foods, such as milk and cream. Milk kept at a few degrees above freezing practically never sours, and it is always a surprise to the housewife who has had no previous experience with such low temperatures to discover how long it will remain sweet in this type of refrigerator. Other undesirable changes may occur at this temperature, however; so it is hardly desirable to use, without cooking, milk that has been kept more than three or four days in such a refrigerator, even though it is still perfectly sweet and shows no signs of decomposition.

In a well-constructed mechanical refrigerator the temperature should not be over 40° anywhere. At such temperatures most bacteria, if they grow at all, grow very slowly; and kinds of food less subject to rapid decomposition than milk (such as meat, vegetables, fruits, and preserves) may be kept for a long time — as long as the housekeeper ordinarily needs to preserve them. The atmosphere in a mechanical refrigerator is usually rather dry, and vegetables are likely to wilt; so it is generally recommended that they be kept in a tight container. Practically all other kinds of food keep better than on ice.

3. Temperature of an Ice Chest. A far less efficient means of obtaining low temperature is by the use of the ordinary ice chest — less efficient simply because the temperature is higher. The temperature of ice chests is variable, depending upon the size of the chest and the amount of ice in it. It will sometimes be as low as 40°, or even lower, but never quite reaches the freezing point; at other times it will run up to 50°, and as the ice melts, the temperature rises to that of the outer air. Food preserved in an ice chest is far less thoroughly protected than in cold-storage plants. The use of the ice chest is simply a means of checking the development of bacteria, but it by no means stops their growth. Food may be preserved for quite a while, although it is sure in the end to undergo certain forms of putrefaction.

The type of putrefaction that occurs in material kept in an ice chest is usually somewhat different from that which occurs in the same material at an ordinary room temperature. The common putrefactive bacteria grow readily at high temperatures, but hardly at all at the temperature of the ice chest. Other types of bacteria, however, grow more readily at the lower than at the higher temperatures, and meat or other food kept in the refrigerator will in the course of time undergo a type of decay due to the microörganisms favored by the low temperature. This decayed meat appears somewhat different from decayed meat at higher temperatures and has a different odor — a fact indicating a different type of putrefaction. Certain peculiar kinds of decay are seen at these low temperatures which are hardly found under other conditions. Occasionally, for example, fleshy foods, particularly those from salt water, like lobsters or fish, develop a peculiar *phosphorescence* if kept in an ice chest. If examined in the dark they will be seen to glow with a somewhat brilliant greenish light. This phosphorescence is due to the development of certain very interesting kinds of bacteria, and always appears if they grow luxuriantly at low temperatures. They grow chiefly upon foods which contain considerable salt, and hence particularly in marine foods. They are more likely to be found in meat preserved in an ice chest, since the more common decay produced by other bacteria will at higher temperatures mask the growth of the phosphorescent bacteria. It is not necessary to throw such food away, since the phosphorescence does not appear to render it unwholesome, and it may be eaten with impunity.

Although far less efficient than cold storage, the ice chest is a means of preserving for a short time food that would otherwise quickly spoil. Its efficiency depends upon its temperature. The larger the amount of ice in an ice chest, the lower its temperature and the greater its efficiency. If the amount of ice is very small there will be such slight lowering of the temperature that food in the ice chest will spoil. Some form of refrigeration is almost a necessity in the household in order to preserve foods which must be kept from a few hours to a day or two before they can be used. This is especially true of the preservation of milk, a topic which we shall notice by itself.

In much of America the ice chest has long been an almost universal aid in the housekeeping of families in moderate circumstances, but at present, in the homes of considerable means, it is being largely replaced by the electrical refrigerator. Very few families now have to do without either type of refrigeration. The home with a refrigerator may purchase food to advantage in quantity and preserve it for a few days till used. The poorer families must rely upon their food being preserved by dealers in food supplies, and can therefore buy only such small quantities as can be used at once.

To keep an ice chest in good condition it must be frequently cleaned. The inside is sure to be damp, and dirt is quite likely to collect in the cracks and corners. This dirt will furnish a good place for the growth of such bacteria as thrive in low temperatures, and thus the ice chest in time becomes unfit for use. Food will not keep well under such conditions, becoming infected with bacteria as well as affected by the odors given off from the decaying material. A frequent cleaning is necessary to keep the ice chest sweet and thus make it possible to preserve food properly.

4. Temperature of a Cool Cellar. It sometimes happens that the only place for storing the autumn products is a cool cellar. This is frequently the case on the farm, especially when considerable material is to be preserved. A cool cellar is of use in any home, for it makes possible the purchasing of fruits and vegetables in bulk during the fall, when they are cheap, and their preservation for use till a later season when they are more expensive.

The value of a cool cellar rests upon two facts: (1) The temperature is usually *lower* than in other parts of the house. (2) It is more likely to be *uniform*. A cellar underneath a house will have during the winter season, at least in cool climates, a temperature not much above freezing. For reasons which we have already considered, such a temperature will preserve fruits and vegetables from bacterial action or other types of decay. Where such a cellar is at hand it is, therefore, very well adapted to the preservation of fruits. Any other room, if its temperature could be controlled, would be just as good, and if it were light would be somewhat better than a cellar, which is usually dark. But rooms above ground are generally lighted by windows, which make it difficult to control the temperature. In the winter such rooms are pretty sure to have a temperature below freezing in the cold climates, and this is sufficient to ruin fruits, most of which are spoiled by freezing.

Since the value of the cellar in preserving fruits and vegetables is simply in its uniform and low temperature, the lower the temperature — provided it is above freezing — and the more even it is, the more satisfactory are the results. On the other hand, a warm cellar, so characteristic of most modern houses heated by furnaces, is of very little use in preserving foods, for decay occurs about as rapidly in such a cellar as it would elsewhere in the house; more rapidly, indeed, than in a cold pantry. Since one can purchase large quantities of many foods more reasonably in the fall by taking advantage of the low market rates, it is economy to have a compartment partitioned off from the heating apparatus in the cellar where fruits and vegetables can be stored.

In the use of a cold cellar to preserve vegetables it is well to bear in mind that many of them — parsnips, carrots, beets, turnips — are better preserved if buried in sand, and that fruits keep better in sawdust, oat chaff, or some other material which absorbs moisture.

Other Devices. Any device for cooling will of course be useful in preserving foods. Cold *running water*, *spring houses*, submerging in *iced water*, are all used for the purpose. Suspension in *deep wells* is one of the most common methods of obtaining a low temperature for milk, butter, etc., and is widely adopted in houses where ice is not at hand. Even the scheme of packing material in *damp leaves* may be of some value, since the evaporation of the water from the leaves lowers the temperature. This principle is often made use of to cool drinks and small lots of food by keeping them in unglazed earthenware receptacles the surfaces of which are constantly moist. The evaporation of the water on the outside cools the inclosed liquids. In the same way automobile tourists keep water cool by suspending it outside the car in porous canvas bags.

Cooling may be used for any kind of food. Three general rules should always be followed where food is put aside for preservation at a low temperature.

1. Cool the food as quickly as possible. This should be done before covering and setting aside for keeping.

2. Use every possible device for avoiding moisture.

3. Use food quickly after taking it from its place of storing, for such food when warmed decays rapidly.

The Use of Heat

The easy destruction of bacteria by heat suggests a means for increasing the keeping properties of many foods. Liquid foods may first be boiled and then cooled as quickly as possible, after which they may be put away in cold places for preservation. It is necessary that the material should actually be boiled, since insufficient heat is not only useless but frequently detrimental. If a putrescible material is simply steeped in warm water and then put away, it will spoil rapidly; if it is boiled it may be preserved for some time. Boiling is useful for such materials as soups, stews, or any liquid not injured by boiling. It must be remembered, however, that boiling will not preserve the material indefinitely; it simply delays the spoiling. It kills the bacteria present, but others can get in later.

CHAPTER XIII

THE USE OF PRESERVATIVES

In early years the only means adopted for preserving food were drying and cooling, both of which have been known and used for many centuries. Within the last fifty years other methods have been used for the same purpose, and for some kinds of food they are far more satisfactory and valuable than those just mentioned. The first which we shall notice is the use of preservatives.

The explanation of using preservatives is that it adds to the food something which will check the growth of microörganisms and thus prevent decay. Such preservatives must fulfill two conditions: (1) They must have some *antiseptic* power. (2) They must be comparatively *harmless* to man.

Poisonous Preservatives

Since we know that the spoiling of food is due to the growth of microörganisms it is easy to find chemical substances which will be perfect preservatives. If it were simply a matter of protecting food from decay, it would be the easiest thing in the world to bring about the result. But it chances that most of the materials fatal to the life and growth of microörganisms are also poisonous to man and therefore cannot be used in his foods.

This greatly restricts the number of materials that can be used for food preservation. Some it is quite impossible to use because of their violently poisonous nature. For example, *carbolic acid* and *corrosive sublimate* will prevent decay perfectly, since they are fatal to bacterial growth; but they are also violent poisons to man and hence must not be put in his foods. There are other chemicals, however, of a less poisonous nature which are frequently used for the preservation of foods.

The milder drugs in use to-day for this purpose are chiefly *borax*, *benzoic acid*, *salicylic acid*, and *formalin.* Although these substances are poisonous and injurious to man when used in considerable quantity, they may be swallowed in small quantities without any appreciable effect upon the individual. But even in small quantities they have the power of checking the growth of bacteria, and they are frequently used for protecting various kinds of food from the spoiling that would otherwise occur.

These materials, put up into proper form for use, can be found in our markets under a variety of commercial names. These various commercial products differ in their chemical analyses, but are all made up of mildly poisonous materials. No two of these preservatives are exactly alike, but most of them are made up, wholly or in part, of the chemical substances above mentioned. At one time a number of such products were sold quite generally, under special trade names; but to-day one rarely finds them offered for sale by retailers in the United States. They are now known to be of questionable value. They are undoubtedly efficient in protecting food from putrefaction and decay, for they all check bacterial growth. If used in sufficient quantity they will wholly prevent putrefaction, and even in small quantities they may so check the growth as to preserve the food much longer than usual. For this reason they are extremely convenient and have been widely used by people who do not understand what they are. It is easy to see how a housewife, after trying them once, might find them so convenient as to give up entirely the use of a refrigerator or other devices for keeping food cool, believing it cheaper as well as more convenient and more satisfactory to employ a preservative than to use ice. The various forms of preservatives may be used for almost any kind of food,— for canning fruits or vegetables, for preserving milk, meat, etc., — and, so far as concerns the actual protection of food from decay, they certainly accomplish their purpose.

But the important question arises whether it is healthful to use such materials in our food. Every one of them is of a more or less injurious nature, and if taken into the body in any considerable amount will produce poisonous effects. This has led to much experimenting and discussion. In past years a considerable portion of the food products on the market was treated with some of these food preservatives, borax being widely used for this purpose. In the markets of Europe some of these substances are used to preserve a large part of the meats, butter, milk, etc. England obtains great quantities of her provisions from Canada and even Australia, and it seems difficult, or impossible, to deliver them at such long distances without treating them with preservatives. At all events, the foods coming from Australia to the markets of England are usually so treated. The use of preservatives in our own country is less necessary, because our markets are nearer the sources of supply. The national Pure Food Law, making these preservatives illegal, has greatly reduced their use, and to-day the food on our markets is mostly free from them.

It has been an open question for some years whether borax used in small quantities under such conditions is injurious to the consumer. Nor is the question yet positively settled. It has become in a measure an international question, involving the importation of American beef and other products into foreign markets, and a great deal of contradictory evidence has been advanced. The fact that people have for years been unconsciously using food preserved by means of such substances, without any apparent injurious effects, seems *prima facie* evidence that no harm results; but it is possible, of course, to say that the harmful effects are not at first discernible, and that many of the digestive and other troubles of man are due to this unconscious consumption of such drugs. No positive answer can be given to the question. Although it is certain that many people in large cities have occasionally, or even constantly, consumed them without any apparent injury, the general belief is that they are injurious.

Moreover, when such materials are used for preserving food, it frequently happens that a considerable quantity is unconsciously used. Our foods usually pass through the hands of several people before they are consumed. The original producer may put in a little preservative, the middleman adds more in order that the material may not spoil on his hands, and the householder, in ignorance of these additions, may put in a little more. By the time it reaches the table it may be so filled with some of these poisonous articles as to be decidedly unwholesome. Instances are known where violent sickness, and even death, especially among children, have been traced to the use of such preservatives, which had been added by one person and another until the food contained them in large quantity. This is particularly true of milk, because it spoils so easily and quickly.

For these various reasons the use of such preservatives is to-day forbidden by law in any food materials offered for sale,[1] and they must also be condemned in the house, since even in small quantities it is possible that their daily use may cause trouble. No housewife should therefore depend upon any of these forms of preservation for her food. They are unwholesome and even dangerous, and their use is likely to be followed by ill health and possibly by fatal sickness. Particularly should it be understood that it is dangerous to add preservatives to food that has previously passed through the hands of others who may have already used preservatives — a condition of things especially likely to occur with milk. Nothing but universal condemnation for the use of the commercial materials can be given the householder. If any preservative is to be used, it is far cheaper and better to buy pure borax from the druggist. For milk or cream this may be used in the proportion of one quarter to one half ounce to six quarts of milk or

[1] By a recent ruling a small amount of benzoic acid is allowed in certain foods. It is a very mild preservative, however, and there is some question as to its value. Some states still forbid its use; and products, such as tomato ketchup, on the markets of these states seem to keep as well as those with a benzoate as sold in other states.

cream; for preventing hams or bacon from molding or becoming slimy, the borax may be dusted on the surface, not more than one quarter of an ounce being used for each pound of meat.

But any one of these materials, if used in considerable quantity, is certainly injurious, and this fact makes it quite out of the question to recommend them for home use. It is quite impossible for the physician, much less the housewife, to know how much may be used without danger.

Nonpoisonous Preservatives

In protecting food by preservatives we are not confined to poisons, since there are a few materials capable of preserving food that are not poisonous but are, on the contrary, beneficial to us. The use of such preservatives is of course perfectly proper. Some of them have been in use for many years and at the present time are more used than ever. The chief ones are mentioned below.

Sugar. As already indicated, bacteria do not grow readily in pure sugar solutions, and if the solutions are very strong they do not grow at all. The other forms of microörganisms also, molds and even yeasts, fail to grow readily in solutions containing a considerable quantity of sugar. It is therefore quite feasible to preserve many of our foods from putrefaction by simply mixing them with a considerable quantity of sugar. Since sugar is an excellent food for man it does not injure the material but increases the food value of the product. As a preservative sugar has more value against bacteria and molds than against yeast. It is the material which readily supports yeast life, and it occasionally happens that materials preserved by it will ferment. But this does not commonly occur if the percentage of sugar is high, i.e. 40% to 50%.

The use of sugar as a preservative is adopted in a number of well-known products. Fresh *fish* is occasionally preserved by rubbing with sugar. *Condensed milk* is preserved by the addition of 30% to 40% of it. It changes the nature of the milk, rendering it somewhat less digestible, but does not materially injure it as a food product. *Jellies* are also preserved from bacterial action, though not wholly from fermentation, by the large amount of sugar which they contain; for decay would take place quickly if it were not present. It has been used for a long time to protect fruits, in making what are known as *preserves*. Almost any kind of fruit may be preserved by stewing it with a large amount of sugar, equal parts by weight of fruit and sugar being commonly used. At a moderate heat the fruit is so thoroughly impregnated with the preservative that no putrefactive organisms are subsequently able to grow in it, and it may then be preserved almost indefinitely. *Marmalades* are also preserved by the same preservative. This is also, in a measure, as we have seen, the reason for the preservation of *raisins*, *figs*, *plums*, etc., which are preserved partly by drying and partly by the presence of sugar. In these cases the fresh fruit contains so much of it that none is artificially added. But most fruits contain too little to be preserved without the special treatment above described. There are of course decided limitations to the use of sugar for this purpose, for the flavors of most of our fruits are changed when mixed with a great deal of it. They cease to have fruit flavors and become a sort of candied material which can be used only as a sweetmeat or a sauce. This method of preservation is used to-day much less than in earlier years before the wide extension of the process of canning.

Salt. A more common, harmless preservative is salt. Materials thoroughly salted are completely protected from bacterial growth. Since salt is harmless and, indeed, a necessary ingredient in our food, such a method of preserving is quite legitimate. Salt is used as a preservative for a variety of food products. *Fat pork* is very easily preserved by keeping it immersed in a strong salt solution called *brine*, producing what is known as salt pork. *Corned beef* and *corned bacon* are also preserved in the same way. *Cheeses* are sometimes preserved in brine, and the same is true of *eggs*. In other cases the salt is mixed with the food. *Hams* and some other meats are preserved partly by salting, and in most forms of dried beef salt is added to assist in the preserving. It is used for the preservation of great quantities of *fish*, particularly marine fish, which may in this way be preserved indefinitely from bacterial action. Fresh-water fish could be preserved equally well, but since they are not generally caught in large numbers they are rarely salted. The salting of *butter* is a procedure adopted partly for the purpose of giving a salty flavor and partly for the purpose of its preservation. In the preparation of *cheeses* salt is almost always used, for after their manufacture they are usually kept for weeks or months before they are ready for market, and salt is rubbed into their surfaces to prevent the growth of undesirable microörganisms.

It must be remembered that, while salting preserves the material from decay, it does not preserve its fresh form.

The flavor is much changed, and too large a quantity of salt meat is not wholesome. Moreover, salt somewhat changes the physical nature of food, so that it is not quite so easily digested. Salt foods, therefore, cannot wholly take the place of fresh foods. This is especially true since they are lacking in the vitamin which prevents *scurvy*, a trouble frequently met with among sailors who have subsisted too largely upon salt foods. Nevertheless such foods are very useful, and if a sufficient quantity of fresh food (or even powdered lemon, as used by recent polar expeditions) is consumed with them they may be used very advantageously as part of our diet. In preparing such foods for the table they should be soaked in water to remove as much of the salt as possible.

Vinegar. Acetic acid is another material used legitimately for the preservation of certain kinds of food products. In its best known form, vinegar, it is the basis of the preservation of all kinds of *pickles*. The acetic acid in these cases serves two purposes: (1) It gives a new flavor to the material, rendering it very sour. (2) It protects the product almost totally from the action of bacteria. The pickling of *cucumbers* has become a great industry, green cucumbers being more extensively used for the purpose than any other material. The vinegar is frequently mixed with spices, both for the purpose of added flavor and to aid in the preservation. Although pickled vegetables keep well, they do not keep indefinitely. Pickle brine sometimes becomes covered with a scum composed of bacteria, and the pickles themselves may grow soft from decay. If the pickles are taken out and boiled for a few minutes, the microörganisms will be destroyed, the trouble may be checked and the pickles preserved. It is practically important to know that pickles should not be kept in glazed ware, since the acetic acid may unite with the glazing and make unwholesome products. Metal covers are especially undesirable, for the same reason. Glassware receptacles are best for the holding of pickles.

In a somewhat modified way acetic acid or lactic acid is the basis of certain other preserved foods. *Sauerkraut*, for example, is cabbage protected from putrefactive fermentation by allowing it to sour in the presence of considerable salt, with the production of acetic and lactic acids. The acid in this case is formed in the cabbage by the growth of acid-producing bacteria, and after it is formed it prevents the growth of other putrefactive bacteria, thus making it possible to preserve for a long time the vegetable material which would otherwise undergo putrefaction. Here we actually have an instance of a harmless kind of microörganism protecting food from the action of other species. A similar food product is sometimes made from *beans* which are allowed to sour and are thus preserved from further decay, while *dill pickles* are similarly made from cucumbers.

Any substance can be preserved from bacterial action if it can be soaked in vinegar or other acid, and it is therefore possible in the household to convert into either sour or sweet pickles a considerable variety of vegetables. In actual practice the use of vinegar for this purpose is very limited, mostly confined to green fruits and vegetables, although fish or flesh is occasionally treated in the same way. The product obtained is used as a flavor to our diet rather than as a food.

Spices. Many of the spices common in the household are more or less efficient as antiseptics, and when added to food material will preserve it from putrefaction. Their use is quite general in certain household products. For example, *mince-meat* is a watery mixture which under ordinary circumstances would readily putrefy. Both the meat and the apple in it would by themselves undergo putrefaction and decay; but when they are made into mince-meat, and spices, boiled cider, and some other materials added, the entire mixture forms a mass which, though not absolutely protected from the growth of microörganisms, is ordinarily incapable of supporting the growth of the putrefactive and decaying bacteria which would naturally appear in the ingredients. The antiseptic effect is produced chiefly by the spices, and if the housewife should leave these out she would have a putrefying mass in a short time. Such material is not, however, completely protected from mold growth. It will keep longer if the apple is left to be added at the time of using, and, of course, it will keep best in a cool temperature. In a warm temperature the effect of the spices is not sufficient to prevent a more or less troublesome fermentation and decay, and particularly molding.

In ordinary *sausages* and *salads* the same principle is concerned. Sausage meat is made of material which is subject to rapid putrefaction, but in cool weather it may be preserved for a long time. Here we have again an example of a readily putrescible material prevented from decay by the presence of the slightly antiseptic spices, like salt, sage, etc. The spices in the sausages have really a twofold purpose. Not only do they protect the materials for a time from putrefaction, but they give to them the peculiar flavor which is desired. In the case of sausages, as in mince-meat, the spices are not sufficient to prevent putrefaction absolutely, and consequently in the warm summer weather it is not very easy to preserve them. Sausages, like mince-meat, are generally made in cold weather, for under such circumstances they may be preserved without trouble for a considerable length of time.

In a somewhat similar way, as we have already noticed, hops are used for aiding in the preservation of a yeast brew. They are also frequently used in making beer, to which they not only impart a desired flavor but also aid in preventing the decay of materials present which would readily support the growth of bacteria. Fruit cake of certain grades is preserved from spoiling chiefly by the spices it contains. Nearly all strong spices have an antiseptic power when mixed with foods, and protect them to a greater or less extent from bacterial action. This fact is made use of quite extensively by different nations; for most countries have special spiced foods preserved in this way, many of which are not known to people outside of the localities where they are made. Spices are thus of much value both as a means of imparting flavor and as a preservative, but they never preserve the original taste of the foods. Many spiced foods are used simply as condiments rather than as nourishment.

CHAPTER XIV

PRESERVATION BY CANNING

The addition of mild preservatives like sugar, salt, spices, vinegar, etc., while it makes possible the preservation of many kinds of food, very decidedly changes their nature. The flavor is totally changed, and in some cases the food is rendered less digestible; hence its food value is lowered. These methods of preserving food are very useful for some purposes, but they cannot be used for all kinds of food. In many cases the change of flavor would be so decided and the change in the nature of the food so great as largely to destroy the material for subsequent purposes. None of the methods preserve the food in anything like its natural condition.

What is Canning?

A method of preservation based upon the simple plan of keeping bacteria away from food products has been devised in the last century. This has come more and more into common use, until to-day it is employed to an almost incredible extent. The method is spoken of as **canning.** The food is not treated by any antiseptic for the prevention of bacterial growth, but reliance is placed simply upon devices for keeping all bacteria from it. If this can be done, the food will not be subject to their action, and will never spoil.

We have already noticed that bacteria are almost universally distributed in earth, air, and water. This fact makes it extremely difficult to protect food from their action, and, indeed, without special devices it is quite impossible to do so. All food material—meats, fruits, or vegetables — is sure to contain bacteria when it reaches the home or the canning factory. From some source, either air, water, or earth, every kind of food material is sure to become contaminated. Every one must recognize, then, that bacteria will be found with absolute certainty in every kind of fresh food.

Hence the process of keeping food by protecting it from bacteria must consist of two steps: (1) Some means must be devised for removing the bacteria already present in the food. (2) The access of all other bacteria must be absolutely prevented. If these two objects can be accomplished, the food will be protected from bacterial action and, thus protected, may be preserved *indefinitely*. Food thus guarded may be kept for any number of months. No limit has ever been found, and we have no reason for questioning that it might be preserved for centuries without any subsequent change, provided it could be kept absolutely free from the attack of microörganisms. This method, therefore, offers almost unlimited possibilities in the way of preserving food for future use. It demands care in its application, but the results, when properly obtained, are permanent.

1. Destroying the Bacteria Present. The removal from any food material of bacteria already present is generally brought about by the action of high heat. We have already noticed that a sufficiently high heat is fatal to all forms of life, and hence the simple heating of food will destroy all bacteria. The material to be canned must be cut up into pieces of convenient size, which will depend somewhat upon the kind of material. In general, the larger the pieces the more attractive the appearance of the product when finished, but the greater the difficulty of canning. Cherries, plums, and berries can be left whole; pears are cut into halves or quarters; while apples are commonly cut into smaller pieces. These pieces are to be placed in water and heated. The process of canning is therefore applicable only to materials that are not greatly injured by immersion in water and subsequent boiling. Hence it is useful for foods which cannot be well preserved by drying.

In the application of heat several points must be borne in mind. 1. It must be remembered that the destruction of the organisms capable of growing in the particular food to be canned must be absolute. If a single individual micro-organism is left alive in the food after the boiling, and finds conditions favorable to its growth, the whole process is useless and the canning will be a total failure. One live bacterium, capable of growing and multiplying, can produce a subsequent putrefaction and destruction of the food with just as great certainty, though not so quickly, as if a million of them were left alive. Therefore, unless the food contains substances which inhibit bacterial growth, the preliminary heating must be a complete sterilization, that is, a heating so thorough that every individual bacterium is destroyed. No halfway processes are of any use whatsoever; it must be total and absolute. This is by no means easy, and most failures in canning are due to the inability to bring about this complete destruction. If a housewife finds that a portion of her canned preserves is spoiled, she may infer that the original heating was insufficient.

2. It must be remembered that the amount of heat required to destroy different species of bacteria is not always the same. While most actively growing bacteria are destroyed by a moderate heat, and quickly killed by boiling, certain bacteria spores, as already noticed, are capable of standing much greater heat. Some kinds of bacteria produce spores that may be boiled for a few moments, or, indeed, for an hour, without being wholly destroyed. From this it follows that a short boiling is not always sufficient to destroy bacterial life. If the food material chances to contain some of these resisting spores, the brief boiling commonly adopted in the process of canning will not kill them, and it will inevitably happen that the food, if canned, will undergo putrefaction because of the growth of the spores that were left uninjured. If on the other hand the food in question does not chance to contain such spores, a few moments' boiling is quite sufficient to protect the material perfectly from later decay.

It is a well-known fact that the process of canning is not equally successful with all kinds of foods. Some substances (*rhubarb*) contain acids that act as partial antiseptics, and can be preserved very easily. Others, like most *fruits*, require a little more care, but are easily preserved; while others, in spite of the ordinary precautions, will frequently show subsequent signs of decay. The canning of *tomatoes* has always given trouble to the housewife. In former years it was thought to be an impossibility to can *green corn*, and the preservation of *peas* and *beans* has proved to be even more difficult. These products are successfully preserved to-day, but until home canning was stimulated by the war-time food shortage they were rarely canned except in factories, for they are far more difficult to preserve in this way than foods containing considerable amounts of sugar or acid. The problem of canning any product, whether it be fruit, tomatoes, corn, or peas, is simply that of totally destroying the microörganisms present that are capable of growing in that particular food. If the material, like most fruits, contains so much sugar or acid that only yeasts or molds are able to grow in it, preserving is quite easy, because simple boiling kills these organisms. Corn, peas, and beans, however, not only furnish a favorable environment for the growth of bacteria, but also are sure to contain bacteria which develop spores (Fig. 63) and can therefore resist considerable boiling. If two or three or even one of these highly resisting spores survives, the canning may prove quite ineffectual. Tomatoes contain considerable acid but little sugar, and therefore stand midway between these two groups of foods. Ordinary boiling is generally sufficient to preserve them, especially if sugar be added, but they are more likely to spoil than are fruits.

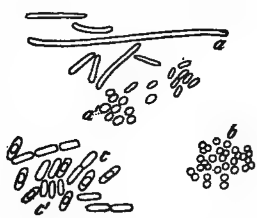


FIG. 63. Spore-producing bacteria found in canned corn.

The remedy in all such cases is higher or longer heating, since no satisfactory means of destroying bacteria is known except the application of heat. Even spores may be destroyed if the proper method is adopted.

Higher Heat. Common liquids, when boiled in open vessels, cannot be heated above 212°, no matter how brisk the boiling; but if boiled in closed vessels under pressure, the temperature may be raised much higher. If the material is boiled under pressure of a few pounds only, a sufficient temperature is obtained to destroy the spores in a comparatively short time. Household devices for cooking under pressure are now on the market, but as they are rather expensive, this method of sterilizing is in common use only in canning factories. This method of heating is called "processing" and is very efficient.

Longer Heating. Higher temperatures are not easily obtained in the household, but the spores may be killed by simply prolonging the boiling. If spore-bearing material is boiled for a sufficient time, the spores are eventually totally destroyed. The length of the time necessary is often as much as two or three hours and depends very largely upon the vigor of the boiling and the nature of the food (see page 201).

Intermittent Heating. Sometimes a better product is obtained if, instead of boiling once for a long time, the food be boiled for shorter periods on three successive days. The principle upon which this method depends is that the spores not killed by the first day's boiling will germinate and be in a condition to be readily destroyed the second day, while the third day's heating takes care of the few that escape both previous heatings. This is known as "fractional" sterilization, because only a part of the bacteria are destroyed at each heating. The length of boiling necessary on each of the three days varies with the kind of food it is desired to preserve.

2. Preservation. After the food has once been deprived of bacteria (*sterilized*), it must be protected from the subsequent access of all kinds of microörganisms. Since bacteria are always present in the air, any of these sterilized products will surely be reinoculated if exposed, and the new bacteria would soon spoil the food. Therefore the practical method of keeping bacteria out is that of sealing the contents hermetically. In the laboratory it is possible to preserve foods without sealing by simply filtering all the air that reaches them through something fine enough to exclude bacteria. Bacteriologists have found that the air which passes through cotton is deprived of all bacteria. If, therefore, any sterilized material is placed in bottles, tubes, or vials which are tightly plugged with cotton, as shown in Fig. 64, it will be perfectly protected from the invasion of bacteria. A knowledge of this fact may be of some practical importance, even in the household, in case it is desired to preserve something for a short time only and one does not want to go to the trouble of hermetical sealing. But such a method is quite impracticable for the ordinary canning of food. At best it is of only temporary utility, for though cotton keeps all bacteria away from the sterilized material, it will not wholly exclude molds, and, moreover, allows the material to become dry. Hermetical sealing keeps food moist as well as sterile.

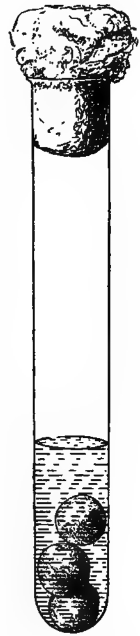


FIG. 64. Preserved cherries, showing that the exclusion of air is not necessary for preservation.

Hermetical sealing, which will prevent all subsequent access of air, is extremely easy to accomplish and is thoroughly effective. The material must be sealed in some proper receptacle *while still hot* from the boiling, for it is at this time sterile and, if sealed at once, has no opportunity of becoming inoculated with more bacteria.

The devices for hermetical sealing are numerous. In earlier days the housewife employed ordinary bottles, which were filled with the material, then plugged tightly with corks, and sealed with rosin or something of the sort to exclude all air. The invention of the modern *fruit jar* with its rubber ring and convenient top has done away with all such crude devices. The fruit jar with its variously devised top (Fig. 65) is a perfectly effectual means of excluding air and hence for keeping out all microörganisms. The significant feature of these fruit jars is the rubber ring *a*, which is clamped tightly upon a flat ledge on the jar *c* by means of the cover *b*, so made that heavy pressure can be exerted upon the rubber. This pressure upon the rubber effectually excludes all air and all bacteria. Fresh rubber rings should be used each time the jar is filled, since the efficiency of the sealing depends upon the softness and elasticity of the rubber; if this gets hard, as it will in a few months, the sealing will not be as effectual. Of course complete sterilization of the jar must be assured. In the cold-pack

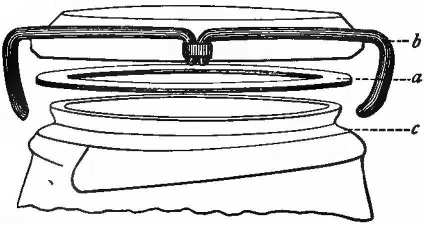


FIG. 65. The top of a common fruit jar; *a* is the rubber ring upon which the success of the sealing is dependent.

method (see page 200) this takes care of itself, as jar and contents are sterilized together. In the open-kettle method it is best to place the jar in cold water before filling, to bring the water to a vigorous boil, and then to fill the jar while still hot. Pouring boiling water into the jar is a simpler method, but is not quite so certain.

The glass fruit jar is almost universally used in the home, is very convenient, and can be used again and again; but in canning factories the use of tin cans is largely adopted, since they are less expensive and are to be used but once. The principle of their use, however, is exactly the same as that of the glass jar, although the details are different. The material to be canned, with or without previous boiling, is put into the tin can, upon which a cover is placed and sealed firmly, the whole now being closed to the air except for a small opening in the cover. Then the can, with its contents, is placed in a convenient heating apparatus for thorough sterilization. Open boiling or pressure heating is used, according to the temperature desired; in the former case the small opening in the cover is not sealed until after heating, to allow the escape of steam, while in the latter case the cans are entirely sealed before processing. Cans are kept under observation for a while to make sure that sterilization has been complete, and any cans found to be swollen from the accumulation of gas within are discarded as ruined. Canning factories have sometimes suffered great financial loss from the spoiling of their products, ordinarily because some highly resistant spores have survived. Canners know to-day that the remedy in such cases is the application of greater heat, and thus are able now to avoid in great measure their losses of previous years.

In canning certain kinds of food it has been customary to add some mild antiseptic to aid in the subsequent preservation. Borax, for instance, has frequently been used to check the development of any bacteria that may be left in meat after the process of canning. From the facts already given it will be seen that the presence of borax in canned foods is totally unnecessary, provided sufficient care is taken in the canning. Its use was a means of covering up a lack of thoroughness in canning, and it has been found in the cheaper products; if the material had not been heated enough to produce complete sterilization, it might still be preserved in cans if sufficient borax were added. In large packing factories where a great amount of food, particularly meat, is to be canned at once, it had become quite common to use a certain amount of such a preservative to cover up this lack of complete sterilization and prevent subsequent loss. The method is, of course, more economical, because it does not require so much heat and because there is a very much smaller per cent of loss. Whether the material thus preserved is unwholesome is a question that has not yet been positively settled, but the sale of it is to-day forbidden by the national Pure Food Law, although benzoate of soda is allowed in certain foods. In household canning it may be given as a universal rule that no preservatives of any sort should be used.

Practical Suggestions. Nearly any type of food can be preserved by canning. Some materials, however, are very much more easily preserved than others. *Meats* are preserved with great ease, but it is rarely worth while in the household to can meat, since fresh meat can be bought in civilized countries at all seasons of the year. When one wants canned meats, it is better to depend upon the product bought in the market than to go to the trouble of canning. The same may be said ordinarily of *corn*, *peas*, and *beans*. All these materials may be canned successfully in an ordinary household, but it requires long heating and special care, and at best there will be many failures. Consequently such materials, when canned in the home, may be very expensive because of the considerable amount that must be thrown away. In the canning factory, however, because of greater experience and better facilities, these foods can be preserved much more successfully and cheaply. When more of these vegetables are raised in the home garden than can be eaten during the summer, it may become profitable to can them at home. During the last war and a few years immediately following this was particularly true because of the food shortage caused by the war. But except under such conditions it is better and cheaper to depend upon the market for canned corn, peas, and beans. The market products are more reliable, under ordinary conditions considerably cheaper, and usually nearly or quite as good as those obtained by home canning.

Most forms of fruit — *apples*, *pears*, *cherries*, *peaches*, *grapes*, *berries*, etc., and even *tomatoes* — are so easy to can that it is generally economical and advantageous to preserve them at home. Material canned at home is usually of a better flavor, because more carefully prepared, and is more satisfactory than much that can be bought in the markets, in the preparation of which wholesale methods are necessary. For the household, therefore, canning is most satisfactory in the case of fruits, and it furnishes a means of keeping for winter use many delightful delicacies.

The Open-Kettle Method. The old household method of canning is to stew the material to be preserved, generally with the addition of considerable sugar, and then after a short boiling to pour it while still hot into jars that have previously been sterilized by boiling. The jars are sealed and the process is complete. This method is applicable principally to fruits that contain so much acid and sugar that the bacteria whose spores resist the boiling are unable to grow. Tomatoes are generally put up successfully by this method, although not so easily as fruits.

The Cold-Pack Method. By the newer methods of canning, as recently advocated by the Department of Agriculture, the food is placed in the jars before heating and is sterilized in the jars. Sterilization is accomplished by heating under steam pressure, by protracted boiling, or by the intermittent method (see p. 194). The finished product is generally improved if the food is *blanched* before packing in the jars, that is, immersed in boiling water for a short time and then dipped once or twice into cold water. This method is applicable to fruits and to nearly all vegetables, but for fruits its advantages over the hot-pack method are perhaps not sufficient to recommend it to the housewife who is familiar with the older method. For different foods different periods of heating are recommended, as shown for some of the more important fruits and vegetables on the next page. For full particulars the reader is referred to the circulars of the Department of Agriculture.

Even the cold-pack method does not absolutely assure preservation. Some loss must be expected, both through spores that escape sterilization and through bacteria that find entrance on account of careless handling or poorly sealed jars.

TIME TABLE FOR COLD-PACK METHOD OF CANNING, AS RECOMMENDED BY THE DEPARTMENT OF AGRICULTURE

(Time given in minutes)

Food	Blanch	Hot-Water Bath	5 to 10 Pounds Steam Pressure	10 to 15 Pounds Steam Pressure	Intermittent, in Hot-Water Bath		
					1st Day	2d Day	3d Day
Corn (sweet) . . .	5	180	90	60	90	60	60
Corn (field)	10	180	60	50	90	60	60
String beans . . .	5–10	120	60	40	60	60	60
Shell beans and peas	5–10	180	60	40	60	60	60
Squash and pumpkin	3	120	60	40	60	60	60
Asparagus	15	120	60	40	60	60	60
Root vegetables . .	5	90	60	40			
Tomatoes	$1\frac{1}{2}$	22	15	10			
Apricots and peaches	1–2	16	10	5			
Cherries and berries		16	10	5			
Apples and pears .	$1\frac{1}{2}$	20	8	6			
Preserves . . .		20	10				

In canning some kinds of food (dried beef, jellies, etc.) that would be injured by the high heat necessary for sterilization, certain packers assist preservation by partially extracting the air from the jar. Such food keeps fairly well, though it is not sterile. It will spoil rapidly if air be admitted to the jar, and at best does not keep quite as well as foods that have been actually sterilized.

A diet of canned foods alone is not wholly satisfactory, although Arctic explorers have learned that they can live upon them much more healthfully than upon salted foods, which were the staple diet on shipboard before the extended adoption of canning. Canned foods are not so rich in vitamins as fresh foods, but their vitamin content is seldom completely destroyed. Different kinds of foods differ in this respect. Thus the vitamins of tomato seem especially resistant to heat and are present in abundance in the canned product. As explained on page 85, there are several kinds of vitamins, each with its own function in physiology, and their exact chemical nature is not yet wholly understood. More accurate information is gradually accumulating in regard to them; and it is not impossible that we will soon know more definitely which foods suffer most in this respect on heating, and why their vitamins are more readily destroyed than those of other foods.

For the present one can merely speak a word of caution against making canned food one's only diet; but as this is never done in ordinary civilized life, canned goods can be regarded as very useful and perfectly safe food products.

CHAPTER XV

THE GROWTH OF BACTERIA IN FOODS

Bacteria in Milk

It is more difficult to maintain a supply of good milk than of almost any other food product. This is due to three reasons: (1) the number of bacteria, under ordinary circumstances, is greater than in any other food product; (2) milk furnishes an exceptionally favorable food for bacteria; (3) the changes which these bacteria produce in milk are very decided and take place with great rapidity. These three factors together make it difficult to preserve milk in the household without exceptional precautions.

The bacteria present in milk are not only numerous but comprise many kinds (Fig. 66). Milk may contain bacteria while still in the udder, and it has a further chance of contamination with microörganisms from a variety of sources, so that a few minutes after the milk has been drawn it may contain organisms in large numbers. The chief sources of these organisms are (1) the bacteria in the milk ducts, which are washed into the milk can during the milking; (2) the dust that is likely to be floating in the air of the barn or milking stall where the milk is drawn; (3) the milk vessels, which are rarely washed perfectly clean; (4) the dirt and filth that are always clinging to the hairs of the cow and which fall into the milk pail during the milking; (5) bacteria from the hands and clothing of the milker.

The number of bacteria found even in fresh milk is extremely great, particularly if the milk be drawn without special precautions for cleanliness. Thousands and even hundreds of thousands are sometimes found in each cubic inch. These bacteria grow rapidly, inasmuch as milk is warm when drawn from the cow, and by the time it reaches the consumer in the city the milk is likely to contain these microörganisms in incredible numbers. The exact numbers, however, are matters of no special importance to us, for fortunately most of the bacteria in milk are harmless. Some of them, indeed, are useful, and, while occasionally troublesome bacteria get into milk, as a rule we may look upon the milk bacteria as doing no injury to the health of the person drinking it (Fig. 67).

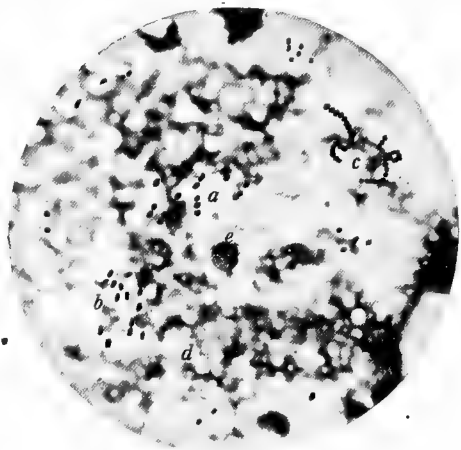


FIG. 66. Milk as seen under the microscope, showing numerous bacteria. *a*, common lactic acid bacteria; *b*, gas-forming bacteria; *c*, streptococci, causing mastitis; *d*, fat globules; *e*, a cell.

Effect of Bacteria upon the Milk. But the housewife is interested in the effect of the growth of bacteria upon the milk itself. The bacteria which grow most rapidly in milk belong to a type known as *lactic-acid bacteria* (Fig. 67). These produce a change in the milk sugar, converting it into lactic acid, which causes the milk to taste sour and curdle. Curdling and souring will never occur if bacteria can be kept out of the milk. Although the souring is a nuisance, it does not injure the wholesomeness of the milk, and sour milk could be used freely were it not for its unpleasant taste. Indeed, souring is, under some circumstances, desirable, since milk properly soured is protected from a variety of other changes far less agreeable. If the lactic bacteria do not cause the milk to sour, it is almost sure to putrefy, and putrefaction is far more unpleasant and unwholesome than ordinary souring. The souring of milk, therefore, is a natural phenomenon, and one that should be expected and desired in milk after it has become a day or two old. Milk which will not sour is *suspicious*, unless it has been kept at a very low temperature for preservation.

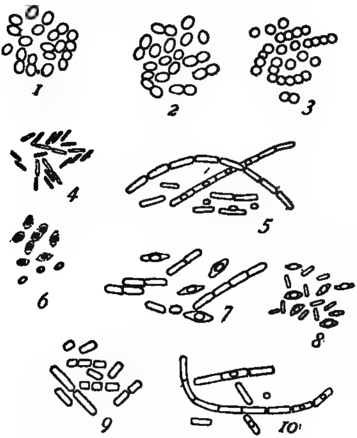


FIG. 67. Group of milk bacteria.

1, the most common lactic bacterium, *B. lactis acidi*; 2, a less common lactic bacterium, *B. aerogenes*; 3, common cocci found in milk; 4, a bacillus producing cheese flavors; 5, a common bacillus with no action on milk, *B. subtilis*; 6, a bacillus causing slimy milk, *B. lactis viscosus*; 7 and 8, common organisms with no action on milk; 9, bacillus causing swelling of cheese; 10, a bacillus causing milk to become putrid.

Sometimes milk a day or two old becomes *slimy* or slippery to the touch, rather sweetish to the taste, and is ruined for all practical purposes. There is no special reason for believing that such milk is unwholesome; but people will not drink it since it is not normal milk. Milk occasionally undergoes a sort of *putrefaction*, becoming *tainted* in smell and taste. Sometimes it becomes *blue* or *red*, and occasionally other changes take place in it. Practically all of these phenomena are due to different species of bacteria, and they may all be prevented if the growth of the microörganisms can be held in check. None of them, however, produce so much trouble in the household as souring, and although, from the standpoint of health, some of these other types of bacterial action are more serious than the souring, the latter is the phenomenon which produces the greatest inconvenience.

Preservation of Milk

The preservation of milk, which commonly means preventing the milk from souring within too short a time, is accomplished only by checking the growth of bacteria. In considering the question of furnishing the household with good, sweet, wholesome milk, several factors are involved which must be considered separately.

1. **Source.** Every housewife should be very particular about the source from which she obtains her milk. This is a matter frequently overlooked, and milk is obtained without special consideration as to its source, upon the general assumption that all milk is alike and that it makes little difference from whence it comes. This is common in the families of the rich and the poor, because the former leave the purchase to servants, and the latter are

likely to buy the cheapest quality. No article of food should be so closely scrutinized, for, although the legal safeguards which the public milk inspection places around our milk supplies insure a tolerably good chemical quality, there is a great difference in the product from different sources. It is an absolute rule that *cheap milk is always poor milk*, and the cheaper the less its value. It is not economy to purchase poor milk, for, although there may be a saving in the original purchase, the amount of food bought is less and the danger attending its use is much greater. Recognizing, then, that its value is in proportion to its cost, we notice the kinds of milk that are to be had in the modern city.

Grocery Milk. The poorest kind of milk that can be purchased is that which the poorer classes use in a few of our large cities. It is bought in small quantities from grocery stores. This method of purchasing is perhaps a necessity for the poorer classes who have no refrigerators, for in warm weather it is quite impossible to keep milk without ice. The store keeps the milk on ice, and the customer buys it in such quantities as can be consumed at once. This would not be a bad arrangement if it were not for the fact that the poorer kinds of milk generally reach these stores, and that the milk is likely to be kept in the stores till it is old, under conditions which make contamination and even watering very easy. As a rule this grocery milk is the least reliable of any milk on the market. It is sold for a small price but is proportionately of poor quality, and it would be better economy for the poorer classes to purchase a better grade. Its sale is now forbidden by law in most of the large cities of the United States.

Milk from Ordinary Milkmen. The milk from the ordinary milkmen varies very greatly in quality, sometimes being of a very high quality and sometimes very poor. There is no way in which the consumer can tell by looking at the milk whether it is good or not. Public statutes and public officials endeavor to guard the milk supply for the benefit of the public, and have so far succeeded that in general the watering and skimming of milk are rare. Chemically, market milk is usually well standardized; but cleanliness, freshness, and general wholesomeness are more difficult to guarantee by any form of public inspection. As a result much filthy milk, quite unfit for consumption, is constantly sold. It is certain that a considerable part of the deaths of infants is directly caused by old or filthy milk.

A method of meeting this difficulty has now been adopted in many progressive communities by a system of **grading**. This consists of having each bottle labeled with a large letter which indicates its grade. The grades adopted are A, B, and C. The exact meaning of these grades varies slightly in different localities, but in general they signify the following: **Grade A** is milk of the best quality, produced in a cleanly fashion, free from disease germs and fitted to be used raw as an infant food. It may be sold either raw or pasteurized, but must be marked to show whether or not it has been submitted to pasteurization. In many communities Grade A pasteurized milk is not sold, as there seems little object in taking expensive precautions to prevent contamination of the milk if it is to be pasteurized and the disease germs in it thus killed. **Grade B** is milk of an equal food value, but the production of which has not been surrounded by quite so great precautions.

Its pasteurization is required; and therefore, although perhaps not so clean or fresh as Grade A milk, it is safe to drink and generally contains fewer living bacteria than Grade A raw. In many communities it is really preferable to the latter, although it costs less. It is usually a good food even for infants, provided some other article (for example, orange juice) is included in the diet to make up for any deficiency in the milk due to the heating. **Grade C** milk is that of lower quality, which is sold for cooking purposes but not for drinking. In many communities Grade C milk is not sold; and thus the purchaser finds himself limited to a choice between Grade A raw and Grade B pasteurized milk. This grading system enables the purchaser to know what he is buying, and has proved a great benefit to the consumer as well as to the milk industry wherever it is adopted. It is necessary, however, to learn whether the grading is done by public officials or by the milkman. If the milk producer or the dealer places the label "Grade A" on his bottles, it means nothing; if the grading is done by official inspectors, it means much. We cannot rely upon a Grade A label unless it is authorized by the public milk inspector.

Certified Milk. In most places in this country it is possible to buy what is called **certified milk**. The meaning of the term is this: A small group of men, largely doctors, constitute themselves a certifying board. Where any milk dealer desires to use the label, this board carefully examines the condition of the dairies from which the milk is produced, together with all methods of handling the milk, and also makes frequent chemical and bacteriological analyses of the milk. If the analysis of the milk and the conditions of its production come up to a specified very high standard, the board gives the milkman the right to use the label "Certified." This label, therefore, carries with it the guaranty of extreme care in production. To carry out all the requirements which these boards make involves much expense in the production of the milk, and as a result the milk sells for a very high price, two or three times the price of ordinary milk. Such milk is certainly of the highest grade, but it is doubtful whether it is any more valuable, and it is certainly no safer, than pasteurized milk of either A or B grade, provided it is protected by proper official inspection.

But our care should not cease with the scrutiny of its source. Even though originally of the highest character, milk will not keep in our homes unless properly treated. The keeping of milk depends upon temperature and cleanliness in the pantry.

2. **Milk Vessels.** Special care should be given to the vessels in which milk is received and kept. A large part of the trouble which the housewife experiences in keeping milk is due not to the milkman nor to the character of the milk which she purchases, but to the condition of the vessel in which she places it. A milk pitcher used day after day becomes filled with lactic-acid bacteria, and any fresh milk poured into such a receptacle will be sure to sour in a very short time. This fact a housewife frequently overlooks. Milk vessels should be cleaned with the greatest of care and should be thoroughly washed with boiling water (not simply hot) in which there is considerable soap. The soap cuts the grease and cleans the dirt from the milk vessels, and the boiling water kills part of the bac-

teria; so that through the agency of the soap and the boiling water the milk receptacles are pretty thoroughly cleaned. Glass vessels are more satisfactory than others, since it is much easier to tell whether they are clean. Glass, however, is easily broken in hot water, and care must be taken in the cleaning. Drying the milk vessels after washing is a process in which perhaps more care is necessary than in the actual washing. If a well cleaned milk pail or bottle is closed tightly immediately after washing and wiping (or even inverted unclosed on a flat surface in such a way as to exclude the air) enough moisture remains in it to permit the growth of bacteria. Such a vessel after a few hours is in a more filthy condition than before washing; if any one questions the statement, let him leave a freshly washed milk vessel tightly closed half a day, then open it and smell the interior! A milk vessel after scalding should be thoroughly wiped, and then allowed to stand right side up and open to the air until next used.

3. **Temperature.** The effect of temperature upon the keeping of milk is more striking than its effect upon that of any other food. Since milk may be frozen, it may be kept in that condition for weeks, months, or even years without change. Freezing has not, however, proved a practical method of preserving milk. But other means of cooling are in constant use. Milk is frequently placed in a cellar, since the temperature is lower there than in the rest of the house. Another widely adopted plan, though not a satisfactory one, is to lower the milk into a well, where, since it is near the water, it is cooled. A more practical and widely used device is the refrigerator, in which low tempera-

ture can easily be maintained. The lower the temperature the better the results; and, consequently, the more ice used the better. The refrigerator has become a practical necessity for families who try to keep milk for even a few hours in hot weather. If not cooled, milk will sour very rapidly. In a moderately warm room it will keep for a few hours only, and in summer it will sometimes sour almost as soon as delivered to the customer. The housewife should therefore place the milk in as cold a place as she can find, *immediately* after receiving it from the milkman. If she does not do this, she must not blame the milkman if the milk does not keep.

One caution must be given in regard to milk preserved at low temperatures. If milk is put in an ice chest with a temperature in the vicinity of 40°, it may keep for many days or even weeks without souring. It is usually assumed that milk is perfectly good and wholesome so long as it is not sour. This is based upon the assumption that the only important change to be feared is souring; so that if it is not sour, it is almost universally regarded as wholesome. Now, although the lactic-acid bacteria do not grow at low temperatures, certain other species do grow readily enough. Milk kept in an ice chest for many days, even though perfectly sweet and showing no trace of souring or curdling, usually contains great numbers of bacteria. The bacteria that grow under these circumstances may cause the milk to become unwholesome, while the lactic-acid bacteria are not injurious, although they render the milk unpleasant. If any unusual smell or taste should appear in milk which has been kept for a day or two in an ice chest, it is undoubtedly wisest to discard the milk.

In a mechanical refrigerator milk can be kept longer than in an ice chest. The temperature close to the cooling coil in such a refrigerator is only a degree or two above freezing, so low as to prevent the growth of practically all bacteria. Milk can retain its fresh taste seven days or more under such circumstances, although it is not well to make a practice of keeping it that long, as it may no longer be safe to drink even though it is unchanged in flavor and appearance.

4. Use of Preservatives. The facts given elsewhere concerning the use of preservatives apply equally in the case of milk. The use of any preservative is always to be deprecated, and, so far as concerns the housewife, the rule should be that no preservatives should ever under any circumstances be used in milk.

It should be borne in mind that none of these devices remove dangerous disease germs. They make it possible to keep the milk longer, but do not make it more wholesome if it chances at the outset to contain any harmful bacteria.

5. Preservation of Milk by Heat. Long before modern bacteriology had explained the reasons for it, heat had been used for keeping milk; and physicians had long recommended the boiling of milk which invalids were to drink, though they did not understand that the reason for the heat was that it destroyed bacteria. In the use of heat for this purpose two different methods may be mentioned.

(*a*) *Sterilization.* By sterilization, strictly speaking, is meant the application of sufficient heat to kill *all* bacteria present in the milk. This can be done only by the use of temperatures above boiling, by methods beyond the reach of a household. While a few years ago there were dairies that did this, to-day the plan has been abandoned except for certain forms of milk put up in cans, like unsweetened condensed milk. Such high heat makes decided chemical changes in the milk which lower its food value.

A far more common method is simply to *boil* the milk. While this temperature does not kill all bacteria, still it has been quite common to speak of it as sterilizing. In hot weather milk is very often boiled to prevent its souring, and in some European countries milk is never drunk without boiling.

The purpose of sterilization is twofold. (1) It delays the souring of the milk. Milk that has been boiled may keep from souring for several days, whereas without boiling it will keep only a few hours. With the poorer families in cities this is the chief purpose of boiling the milk, since it will not keep more than a few hours without ice, and they have no ice chests where it can be preserved from souring. (2) The destruction of disease germs. Milk is a common means by which certain contagious diseases are distributed through a community. The diseases in question are produced by bacteria in the milk, and boiling destroys them. This is the ground upon which physicians and health boards have in the past so widely advocated the boiling of milk that is to be used for drinking. Since boiling does destroy practically all the disease germs liable to be in milk, it makes it incapable of distributing contagious diseases.

There are certain *disadvantages* in boiling milk. The taste is wholly changed, for boiled milk is quite a different article from raw milk. Most people do not enjoy the taste of boiled milk, and the adoption of sterilizing or boiling will therefore greatly reduce the amount of milk used as a food. It might indeed be possible to learn to enjoy the taste of boiled milk. Children brought up on it like it, while they cannot endure the taste of raw milk. A more serious objection to sterilization is that the heating so changes the nature of the milk that it is less easily digested and assimilated. Boiled or sterilized milk can be digested and assimilated readily enough by persons with strong digestive powers, and many children are satisfactorily brought up on it; nevertheless it is somewhat more difficult to digest and assimilate than raw milk, and frequently children with weak digestive powers do not flourish when fed upon such milk. This fact has prevented the widely extended use of sterilized milk.

(*b*) *Pasteurization.* The objections to boiling milk have led to a different method of using heat for milk preservation. **Pasteurization** has come into wide use in the last few years. It consists of heating milk to a temperature of 145° to 170° and maintaining this temperature for from ten minutes to half an hour, according to the temperature used. In this country it is most common to use the lower temperature of 145° for half an hour. After heating, the milk must be cooled rapidly.

It may seem strange that the use of a lower temperature should be more satisfactory than boiling, but the reasons are simple. The chief results to be accomplished are to make it possible to keep the milk longer and to kill all disease germs, and at the same time not to affect the chemical nature of the milk. A temperature of 145° for half an hour destroys all the disease germs liable to be in milk, kills most of the lactic-acid bacteria so that the milk will keep longer, and at the same time does not produce the chemical changes which a higher temperature will. Pasteurized milk at this temperature does not have the taste of boiled milk and is as easily digested as raw milk.

In an ordinary household it is almost impossible to find any servant in the kitchen who can satisfactorily use a thermometer, and even the housewife herself would hardly undertake to heat milk at a temperature of 145° for half an hour.

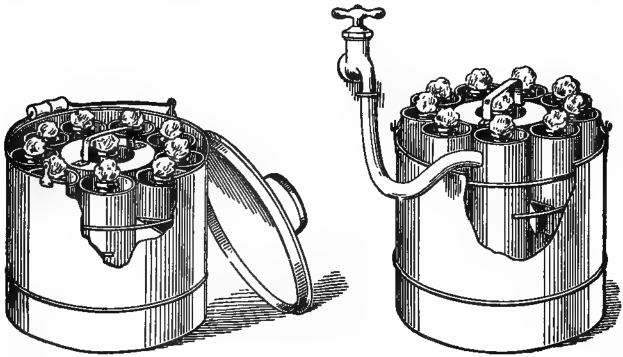


Fig. 68. Apparatus for home pasteurization of milk. The figure on the right shows method of cooling the milk by running water.

The only way it can be accomplished is by some device which will bring about the result in a simpler way. The most convenient apparatus for this purpose is that shown in Fig. 68. This consists of a series of bottles which readily fit into cylinders placed in a larger vessel. This receptacle is filled with boiling water, and the bottles, filled with milk, are placed in the cylinders. The whole is set aside to cool. The milk is warmed by the hot water surrounding it, and the water is at the same time cooled by the milk. The size of the vessel is so proportioned to the bottles that, when properly used, the milk is heated to about the temperature desired before it begins to cool. The method of using this pasteurizing apparatus is extremely simple and can be followed satisfactorily in any kitchen.

Where such an apparatus is not obtainable, the same object can be accomplished in a still simpler way. Place the milk in quart glass jars. Fill a pail with boiling water and place the jars of milk in it. The amount of water should be such as to come nearly up to the top of the jars. The pail should then be set aside to cool, and the milk should occasionally be stirred. The result is that the milk is warmed to about the temperature desired before it begins to cool. After the heating, the milk should be cooled rapidly by running cold water into the pail, this step being as important as the heating.

The adoption of pasteurization has been very rapid in recent years. The primary reason for this is the growing realization of the fact that in no other way can the public be protected from diseases distributed by milk. That it has been found impossible to guard the milk supply so as to avoid such dangers is shown by the fact that epidemics of scarlet fever, septic sore throat, etc. have been traced to certified milk, which has had almost all conceivable safeguards thrown around it. Pasteurization alone renders it safe. Hence we find some cities passing ordinances requiring all milk to be pasteurized, except such as comes from tuberculin-tested cattle. Hence too we find as a rule that Grade A milk is sometimes pasteurized, while milk of Grades B and C is always thus treated, to give the milk a guaranty of safety. It is certainly unsafe to feed babies upon ordinary unpasteurized market milk. For these reasons the pasteurization of market milk on a large scale has been rapidly adopted in the larger cities, until it is possible to purchase pasteurized milk in almost any large community.

Pasteurization, to be really efficient, must be carefully done. A lower temperature than 145° would be useless and indeed sometimes might increase rather than decrease the numbers of bacteria. One of the objections raised against the practice is that in large dairy concerns the pasteurization is done hastily and carelessly, so that the milk is injured rather than benefited. To meet this objection various communities are requiring that the pasteurizing apparatus and process shall be under official supervision and control, thus insuring its thoroughness. When pasteurization is carried out under official inspection, the milk may be relied upon as safe. In no other way can the public be guaranteed that its milk supply may not spread contagious diseases.

Two objections have been urged against pasteurized milk. The first is that it has a tendency to encourage carelessness in handling the milk. The dairyman might feel that since the milk is to be pasteurized, it is not necessary for him to be particularly careful in its production and handling, since any bacteria that get into it will be subsequently killed. This objection is met by the growing requirement that the milk must reach a certain standard of cleanliness and freedom from bacteria before it is submitted to pasteurization.

A second widespread objection has been that pasteurized milk is not quite so good a food as raw milk. This objection has been based chiefly upon the fact that pasteurization as carried out in earlier years, at temperatures as high as 170° or more, did produce changes in the milk similar to those produced by boiling, which rendered the milk less easily assimilated by infants. This objection hardly holds against the American pasteurization temperature of 145°. But even against this low temperature it has been insisted that pasteurized milk is not suitable for infants as a *sole* article of food. It has been claimed that pasteurization destroys some of the *vitamins* normally present in milk, those poorly understood bodies whose presence in our food is so necessary. Hence it is insisted that babies brought up on such pasteurized milk have a tendency to develop a mild form of scurvy which children given raw milk do not have. Whether this is true or not, it is no argument against the use of pasteurization. It is an argument simply against milk as a sole article of diet for infants; for when other foods are included in the diet, or when vitamin-rich materials such as orange juice or even extract of potato peelings are added, the objection disappears. Doctors to-day, therefore, quite generally recommend that when pasteurized milk is to be fed to babies orange juice should be given either with it or separately. For adults nothing of this kind is necessary, since adults feed upon a mixed diet.

It will be perfectly clear that the fact that pasteurization of milk is the only way of insuring its safety is a sufficient answer to the arguments against it, especially since all objections may be readily met by the methods above mentioned. Pasteurization is not a substitute for cleanliness, but an added safeguard. The best milk for the home is the cleanest milk obtainable, which should be subsequently pasteurized to remove accidental dangers that may have reached it, and used with a little orange juice if it is to be fed to young children.

One caution should be given regarding the use of pasteurized milk: the milk must be used quickly after pasteurizing.

It is true that such milk may keep for two days without difficulty, but bacteria are growing in it all the while; and although the milk does not sour, it soon becomes unfit to drink. Hence pasteurized milk must be used quickly, — at least within twenty-four hours from the time when it was pasteurized, — and meantime it should be kept cool just as if it had not been pasteurized.

The most important rule in regard to the use of milk in the household is that it should be used **fresh.** No method of keeping it can prevent all bacteria from growing, and although the use of refrigeration, pasteurization, or sterilization may keep it in a drinkable condition for a day, two days, or even longer, it is always open to suspicion after it has been kept for this length of time. Milk is plenty old enough by the time it reaches the house, and it should therefore always be used fresh. It is far better to obtain it frequently, in small quantities, using it up as soon as possible after it reaches the home.

Preservation of Eggs

Eggs prove to be particularly difficult to preserve. They are sure to contain bacteria inside the shell, deposited there before the egg was laid. These will in time cause the egg to spoil. Eggs cannot be sterilized by heat, for this cooks them. Drying, of course, alters their nature. The use of low temperatures will preserve eggs as well as fruit. They may be protected from actual spoiling for some time by placing them in certain liquids that keep away the air. Brine is used, and water glass is even more successful. To use the latter, mix the water glass purchased at the drug store with ten times its bulk of water, and keep the eggs in the mixture. They will remain in a usable condition for a long time, though they lose their fresh taste. No means are known by which this can be preserved.

Effect of the Growth of Bacteria upon the Wholesomeness of Food

The question whether the growth of bacteria in the food necessarily renders it unwholesome remains yet to be considered. It is evident that after any food material has become completely putrefied it is quite ruined for all food purposes. The vile tastes and odors become so strong that no one can relish food that has entered the later stages of putrefaction. But how about the earlier stages, when the flavors and odors are so slight as to indicate that bacteria have only begun their action? In other words, are we likely to eat food which has begun to be decomposed by bacteria; and if so, is such food unwholesome in any respect?

We cannot regard any material as harmful simply because it is a product of decomposition or contains such products. A number of such decomposition products are in more or less constant use. *Alcohol* is in a sense a decomposition product produced by yeast. It certainly is used to a very great extent, and probably, when used only in small quantity, causes no very considerable injury. *Vinegar* is also a decomposition product from the growth of bacteria, and is used freely by the human race without injury. The flavors of our high-priced *butter* are due to bacteria, and the extremely valuable flavors of cheeses are due, in many cases and perhaps in all, to decomposition products developed in the curd of milk by the action of certain microörganisms. *Sauerkraut* is a preparation which is allowed to undergo an incipient decomposition the flavors of which give the peculiar character to this food. That sauerkraut is a harmless food product is, of course, perfectly evident. In *gamy* meat we have flavors of decomposition produced by microörganisms. The very common use of such partially decomposed meats, and the fact that many persons are exceptionally fond of them, are indications enough that they are not appreciably harmful. These illustrations are sufficient to show that the simple fact that food contains decomposition products is not sufficient to make it unwholesome, since many decomposition products are distinctly desirable in our foods. The flavors of cheese in particular are very useful, for when eaten with coarse bread they give relish to otherwise rather tasteless foods.

Encouraging the Growth of Bacteria in Food

In all the food products mentioned in the previous section, cheese, vinegar, and so on, the growth of bacteria is actually encouraged. To what extent is the housewife concerned in learning how to use bacteria in the manufacture of these foods? Vinegar is never made in the city home, butter seldom, and few kinds of cheeses are homemade products. Nevertheless certain of these processes are useful to the housewife and should be understood.

Cottage cheese is often made at home. It is a very useful way of saving milk that has soured. If the milk has already soured before the housewife decided to make the cheese she does not have to encourage the growth of bacteria, because they are not concerned in the manufacture of cottage cheese except in the souring and curdling of the milk. If the milk is sweet, it first has to be soured, which should be done by placing it at a temperature of about 70 degrees for a day or two. The rest of the process is to remove the curd and press out the whey. Other kinds of cheeses are made from milk curdled with rennet instead of by the action of bacteria, and these microörganisms grow subsequently in the curd, and thus produce the flavors; but the process involved is not well adapted to home manufacture.

Butter is seldom made at home, except on the farm. When it is, little attention is paid to control of the bacteria. The cream is soured (ripened) by bacterial action, and after that the process of churning is mechanical. If the wrong bacteria take part in the ripening, the flavor is bad; but a good flavor can be brought about without real souring. In modern creameries the ripening process is being continually shortened, till at present much cream is churned while still sweet.

A food-making process dependent upon bacteria which the housekeeper is much more apt to undertake is the manufacture of sauerkraut or dill pickles. The principle involved in making both is the same. The cucumbers or the shreds of cabbage are packed in a jar, with considerable salt, and allowed to stand under a weight so that the juices will be extracted. Fermentation then takes place. On account of the salt, few of the decomposition bacteria can grow, and acid-forming types develop something like those that sour milk, although not the ordinary lactic-acid bacteria. These gradually change the nature of the cabbage or the cucumber until the flavors characteristic of sauerkraut or dill pickles develop.

There is a trick to making sauerkraut, and by no means all the homemade or even the factory product is satisfactory. Sometimes it putrefies instead of merely souring, and the flavor becomes disagreeable. One important factor in preventing putrefaction is the quantity of salt employed; one should use 2.5 per cent, that is, four tenths of an ounce for each pound of cabbage. A second important factor is the exclusion of air, as the desired bacteria grow in the absence of air and the growth of other kinds must be prevented. This can well be done by covering the jar with a piece of cloth on top of which is placed a paraffined board cut just to fit the jar. Weights are placed on this to the extent of bringing the level of the juices up to the board, but no higher. It should be watched carefully for a few days, and weights removed or added so as to maintain the proper level of the liquid. Using these simple precautions any one should be able to make good sauerkraut.

Bacterial Poisons in Foods

But, on the other hand, there are unquestionably such products which are harmful and which, even though present in small quantity, may be decidedly harmful or even poisonous. When certain kinds of microörganisms grow in food material, they give rise to a class of decomposition products which are sometimes, although from the chemical standpoint incorrectly, called *ptomaines*. They are usually the result of bacteria growing in animal products; and while some of them are quite harmless, others are of an intensely poisonous nature. If such substances develop in food, they may render it unwholesome or even fatally poisonous. To such poisonous decomposition products are due instances of poisoning from eating *cheese*, quite a number of which are on record. A similar cause explains the still larger number of cases of *ice-cream* poisoning, when many people have been rendered seriously and even fatally sick by the eating of ice cream. Similar effects have sometimes resulted from the use of *milk*, although such cases are rare. Many cases of poisoning are recorded from the use of *meats*, *fish*, and sometimes other foods.

The poisoning in all such cases must not be confused with diseases produced by bacteria. Sometimes food may contain disease germs, and these may enter the body when the food is swallowed, and by growing inside of our bodies produce disease. (See Chapter XVI.) But in cases of poisoning from eating food the bacteria grow simply *in the food*. They do not live in the body nor do they produce any definite bacterial disease. The effects are due simply to the products of decomposition which have been developed in the foods by certain kinds of bacteria.

These troubles are much more common than we are apt to realize. Since bacteria grow best at high temperatures, it is not surprising to find more cases of food poisoning in warm weather. It is not an unknown occurrence to have a general poisoning follow any one of the innumerable banquets held in our communities. Hundreds of cases of intestinal trouble occasionally follow such banquets. The illnesses resulting are rarely serious, but temporarily they produce great inconvenience and trouble. They are probably due to the development of toxic substances in some food products, since almost any of the putrescible foods which come upon our tables may, in warm weather and under certain circumstances, undergo a type of putrefaction which gives rise to these poisons. When this occurs, "ptomaine poisoning" is quite likely to follow the use of the foods. It is probable that a large part of the *summer diarrhœa* so common in warm weather is due to poisonous decomposition products developed in some of our foods.

Unfortunately we know very little concerning the conditions under which such poisonous materials appear. Not all bacteria produce them, and it is only rarely that food is thus rendered unwholesome by bacteria. We know that strictly fresh foods never contain these poisons. We know that their development is dependent in a measure upon temperature, inasmuch as they do not develop in food that is kept sufficiently cold. We know that decomposition products are more likely to give rise to toxic substances in the absence of oxygen than in its presence. We know, lastly, that injurious substances are produced by bacteria; but we do not yet know the source of the bacteria, nor have we, for this reason, discovered any methods for keeping them from our foods other than those ordinarily adopted for checking bacterial growth. Anything that will prevent bacteria from growing will prevent "ptomaine poisoning." Consequently low temperature, drying of foods, and the other devices already suggested are the only means we have for guarding ourselves from such troubles. We may well remember that such poisoning is most likely to occur in foods that have been kept for some time in a moderately warm temperature.

The use of fresh foods and the preservation at low temperatures of any food that must be kept for some time are the only rules that can be given at present for preventing such instances of poisoning. Eat food fresh when possible; keep it cold if it must be preserved; do not keep it any longer than necessary. When food begins to have the smell of decomposition it becomes open to suspicion, although this does not mean that it is necessarily dangerous, since many of these decomposition products are quite harmless. The food products that seem to give the largest amount of trouble are ice cream and fish, and it is therefore desirable to be particularly on one's guard about their use in warm weather and, if possible, to use only that which is fresh or has been made from fresh materials. Since the dangers are greatest in summer, we should be particularly careful at this season not to allow any putrescible food to be warmed by the sun or by standing near a stove.

CHAPTER XVI

DISEASE BACTERIA

The bacteria hitherto studied are all **saprophytes.** There remain for consideration those that can carry on their life within the body of living animals and plants, namely, the **parasites.** The distinction between parasites and saprophytes is not a sharp one, for while some species can live only in lifeless material, and others only in living material, there are many that can live either a parasitic or saprophytic life. When the bacteria grow in the body of a living animal or plant, they may give rise to disease, and these parasitic bacteria are therefore called *disease germs*, *pathogenic bacteria*, *disease bacteria*, etc.

How Bacteria produce Disease

The disease germs are all capable of growing and multiplying in the body, but the habits of different species of disease bacteria are widely different. Sometimes they become distributed all over the body, developing rapidly in any part, perhaps even in the blood. In such cases the disease produced by them is not located at any particular point, but distributed all through the body. This is true of certain forms of so-called *blood poisoning*, or *septicæmia*. On the other hand, it sometimes happens that the microorganisms become located in very definite parts of the body, and while able to grow in certain places are unable to grow elsewhere. In these cases the disease produced may be local, although secondary general symptoms may appear, as is true of *diphtheria*. Between these two extremes are many intermediate types.

Whenever bacteria obtain a foothold in the body they multiply more or less rapidly, and have the same general power of forming decomposition products and secretions as they have when growing in lifeless food. These new substances arising in the body are as varied in nature as are those produced by the common saprophytes. Among them are almost sure to be some that are distinctly poisonous, which we call *toxins*. These toxins may be either decomposition products or bacterial secretions; but however they are produced they are liable to be absorbed by the blood, and the body may thus be directly poisoned by them. If the bacteria are in the blood itself, this poisoning is easy to understand; but localized diseases are similarly explained. Diphtheria, for example, is produced by bacteria growing on the inside surface in the throat. The bacteria themselves do not enter the body, but their excretions are absorbed rapidly enough. Growing in the throat, the bacteria develop very powerful toxins, and these are absorbed from the throat into the blood, producing a general poisoning of the whole body. Sometimes the germs grow in the intestine (*Asiatic cholera*), and their poisonous secretions are absorbed with the digested food. Something similar is true of practically all disease germs. All produce poisonous materials which are absorbed by the body, and these cause the direct injury characteristic of the various diseases.

Not all the bacteria which secrete poisons are disease germs. Some saprophytes may produce deadly poisons, but since they are not able to grow in the living body they are never in a proper sense the causes of disease. They might, however, grow in our food and render that poisonous, so that if it were subsequently eaten it would give rise to cases of food poisoning such as already noticed. Such troubles are cases of toxic poisoning but not true diseases. A true germ disease is caused by the germs themselves entering and multiplying within the body. When the poisons and not the bacteria are absorbed by the body, the sickness comes on very quickly and violently, — an hour or two after the poisonous food is consumed. But it is also of short duration, for, if the amount of poison absorbed is not sufficient to produce death, it is quickly excreted from the body, and a day or two afterward the person will have perfectly recovered, except for the weakening effects of the poisoning. This is the general history of cases of poisoning from ice cream, etc. A true disease acts very differently. It is slow in appearing, gradual in its development, and very slow in disappearing.

The Course of Bacterial Diseases. The diseases produced by bacteria have different histories in the body; but a considerable number of them, with many of which the housewife is intimately concerned, have a course somewhat as follows. For some days after the bacteria enter the body they have difficulty in maintaining a foothold. Sometimes, indeed, even though they succeed in entering, they are driven out by resisting powers which the body possesses but which we cannot here particularly consider.

If, however, they overcome these resisting forces and gain a foothold, they then begin to develop, so that in the course of a few days they become quite numerous. As they grow they produce their toxins, and these, developed at first in small quantity, are absorbed by the body and give rise to the first slight symptoms characteristic of the particular disease. But the bacteria continue to multiply and produce their poisons in greater and greater abundance. As a natural consequence the body becomes more and more influenced by them, the symptoms of the disease become more and more violent, the person becomes more and more ill. This continues until *death* occurs or a *crisis* is reached. After the crisis the bacteria begin to disappear, and are finally driven from the body, while the poisons they produced become less capable of causing injury and are eventually excreted. The person may then recover entirely from the attack.

Resistance against Disease

In most cases the body in driving off the bacteria acquires the power of guarding itself from a second attack of the same species, and the individual, for a time at least, is not liable to a second attack of the same disease. The whole explanation of how the body protects itself, drives off the invading bacteria, counteracts their toxins, and retains this power of protection in the future, is one of the interesting problems upon which bacteriologists are still studying. We cannot here enter into the subject, but it is well to remember that a recovery from common contagious diseases, like *smallpox*, *scarlet fever*, *measles*, *mumps*, *whooping cough*, *typhoid fever*, *diphtheria*, *grippe*, *tonsilitis*, etc., protects the individual for a time from a second attack. The protection lasts much longer in some cases than in others, and whereas the protection against the diseases at the beginning of the above list lasts for years or for life, the protection against those at the end of the list lasts for only a few months or weeks.

Two important facts in regard to the resistance against disease must be mentioned. The ability of a person to resist an attack of any kind of disease germ is dependent upon two things.

1. The *vigor of the bacteria*. It has been learned by experience that the bacteria reproducing any definite diseases are more virulent at some seasons than at others. A very vigorous lot of bacteria will give rise to a more serious attack of the disease, and will be more difficult to drive out than a lot of the same kind of bacteria that have been weakened by some unknown conditions. It is a well-known fact that some epidemics of smallpox, measles, etc., are milder than others; not simply because fewer people are attacked, but because those who are sick have the disease in a milder form. This difference in the severity of the attack is due in part to a difference in the vigor and activity of the bacteria that make entrance into the body, and is a matter beyond our control.

2. The *vigor of the body* itself. A vigorous, healthy, active body has a power of resistance sufficient to drive off most kinds of these invading parasites. If, however, the body is less vigorous, less active, i.e. in a low state of physical health, its resisting power is less and the body has great difficulty in driving off the invaders. This resisting

power, then, depends upon the vigor of the physical health. Hence it is of the greatest practical importance for every one to remember that robust physical health is the best protection against many types of disease due to the invasion of bacteria. It is true that persons in apparently perfect health may take these diseases, but it is nevertheless the rule that the stronger the physical vigor the less is the likelihood of being attacked. At any rate a person of strong constitution will have a milder attack of the disease than one whose physical activity is weakened.

Distribution of Contagious Diseases

While these problems are of the utmost importance in every household, hygiene does not properly belong to the field of our study. There is one phase of the subject of bacterial diseases, however, that is of vital interest to every housewife. If contagious diseases are due to the growth of bacteria or other microörganisms, it is clear that they may be avoided if we can prevent the disease germs from reaching the healthy individual. We have already noticed how one bit of decaying fruit contaminates another, the spores passing to the perfect fruit and causing that also to decay. We have seen how the minute spores of molds and yeasts are scattered through the air and blown about by the winds until they are almost sure to be found everywhere. We have noticed, also, how readily bacteria are distributed, and how surely the air of our houses is filled with them. We have learned that these microörganisms are so abundant in the air that they are sure to get into any exposed bit of food, and we have seen that one of the housewife's duties is to protect her food from their action.

Very similar but more serious problems arise in the household in connection with the distribution of disease germs. If a disease is produced only by the development of bacteria, of course it may be prevented if we can discover some means of keeping the disease bacteria from the body. In canning fruit the housewife tries to prevent bacteria from reaching it. Can she not by a similar principle protect her children from contagious diseases? This problem is the one feature of contagious diseases that belongs primarily to the housewife. The prevention of the distribution of such diseases is a subject which the physician can handle only indirectly, because it depends upon conditions in the home which he cannot control. The modern trained nurse may be able to do this; but in the majority of cases the whole problem of the prevention of the distribution of contagious diseases from individual to individual must rest upon the home maker. The doctor comes in for a few moments only, the nurse is only occasionally at hand, and the duty of protecting the inmates of the home from disease must fall upon the one who is at the head of it. To do it she must proceed according to the same principles by which she protects her food from decay. As she is obliged to use devices to keep bacteria away from all putrescible food materials, and as she must keep decaying apples away from the perfect ones, so it is her duty to guard the members of her family from the invasion of the disease germs.

In her battle against disease the housewife should remember three things.

1. The causes of these diseases are *real things* and not simply matters of imagination. They can be seen with the microscope; they feed; they grow and multiply like larger animals and plants. Contagious diseases are not mere nervous affections that may be banished by forgetting them and believing in their nonexistence. They are produced by definitely known living beings, and can be avoided only by keeping our bodies free from them.

2. The causes of the diseases in question are always *microscopic*, and can never be detected by the naked eye. Material which cannot be seen may therefore be filled with microscopic parasites which are capable of producing fatal diseases. An invisible particle of moisture in the air may harbor deadly germs ready to invade the living body and produce trouble. Since the foes cannot be seen, the battle is a blind and therefore a difficult one.

3. These agents are *alive;* they grow and multiply. Thus it follows that infectious material may rapidly increase in quantity. A particle of dust containing only a few parasitic bacteria may be the starting point of a disease which may spread widely until it shall become an epidemic with its scores of victims. The problem to be dealt with is something like that of fire. The flame of a single match is very slight and may do little injury; but this same flame may start a conflagration that will burn an entire city. So with the disease bacteria. Each of them, although extremely minute, is capable of developing with wonderful rapidity, and a single one may develop sufficiently in the course of a few days to be scattered far and wide, causing a great epidemic. The extreme minuteness of these foes and their wonderful power of

multiplying are the most prominent facts to be borne in mind when contending with contagious diseases. We must not, therefore, think that anything is safe from contamination with bacteria because it looks clean. The eye may not see the contamination even when it is present. Clear, sparkling water may sometimes contain deadly bacteria, while dirty water may be perfectly safe to drink. Nor must we think any substance safe because it has only an extremely small quantity of infectious material upon it, for bacteria can grow so rapidly that a half dozen may become millions in a few hours if they have a chance to feed and grow.

CHAPTER XVII

PREVENTION OF DISTRIBUTION OF CONTAGIOUS DISEASES

What are the diseases against which the housewife must be on her guard lest they distribute themselves through her home? They are evidently those due to microscopic parasites, either bacteria or other forms of living things. Not all forms of sickness are due to parasites, for some have an entirely different cause. But the diseases with which we are here concerning ourselves — the so-called contagious diseases, which are well known to be "catching" and which pass from the patient to a healthy individual — are due to parasites.

The chief of these diseases are *smallpox*, *scarlet fever*, *diphtheria*, *measles*, *mumps*, *whooping cough*, *tonsilitis*, and *influenza* or *grippe*,—all known to be contagious. In addition there are other diseases, serious but much less contagious; so slightly contagious, indeed, that until quite recently they have not been looked upon as being capable of passing from individual to individual. The most prominent and important are *typhoid fever* and *tuberculosis*. The best-known form of the latter disease is commonly known by the name of *consumption*. Formerly neither typhoid fever nor consumption was supposed to be contagious, but it is now known that under some conditions they pass from patient to healthy individual. Lastly may be mentioned a class of diseases not in any proper sense contagious but produced by parasitic organisms which may under peculiar conditions pass from individual to individual. Prominent among this last class are *malaria* and *yellow fever*, diseases never known to pass directly from one person to another but which may be distributed from individual to individual through an agency to be noticed presently. It must not be assumed that science at the present time knows the cause of all the diseases here listed. Some of them, indeed, like measles and mumps, while almost certainly caused by microörganisms of some sort living in the human body, have not yet been satisfactorily explained, and we do not know the actual germs which cause them.

There are some other contagious diseases besides those mentioned, for almost any trouble that produces open sores anywhere on or in the body is likely to be distributed from person to person. Those mentioned are, however, the most important.

Conditions of Contagion

To make it possible for a disease to pass from one person to another, three conditions must be fulfilled: (1) The microörganisms which produce the disease must find some means of *exit* from the patient. (2) The organisms must in some way be *carried* from the patient to the healthy individual. (3) The organisms must find some means of *entering* the body of the healthy individual. If the parasites can meet these three conditions, the disease will be carried from patient to well person. For a proper understanding, therefore, of the way to handle contagious diseases in the home we need to consider these three factors.

If we know how the bacteria leave the body of the patient, how they are distributed, and how they enter the body of another, we are well equipped to guard against them.

1. *The Means of Elimination from the Body*

A knowledge of the means by which the contagious material leaves the body of the patient is of first importance in preventing the distribution of such material, and this should always be the first point inquired into in the practical study of any contagious disease. There are several different methods.

The parasites that produce certain diseases do not find any direct means of being eliminated from the body, and when this is the case the disease is not in any proper sense contagious. *Malaria* is the best example of this class of diseases, and *yellow fever* is a second. *Malaria, chills and fever*, and *fever and ague* are all names for the same disease, produced by a microscopic parasite living in the human blood. Growing there, it develops poisonous secretions, and these acting upon the body give rise to the symptom of chill followed by fever only too well known in this disease. The parasite is a minute little body (Fig. 69, 1) which enters the blood corpuscle. Inside this corpuscle it grows, and finally breaks up into many little bodies, or spores. As soon as the spores are formed, the blood corpuscle breaks to pieces, setting the spores free and at the same time liberating the secreted poisons. These poisons cause the chill followed by fever well known in malaria. The spores may then enter into other blood corpuscles and go through the same history again

(Fig. 69, 1–7). It takes about forty-eight hours for them to complete their history, and hence the chills, in the common form of malaria, occur every other day. One

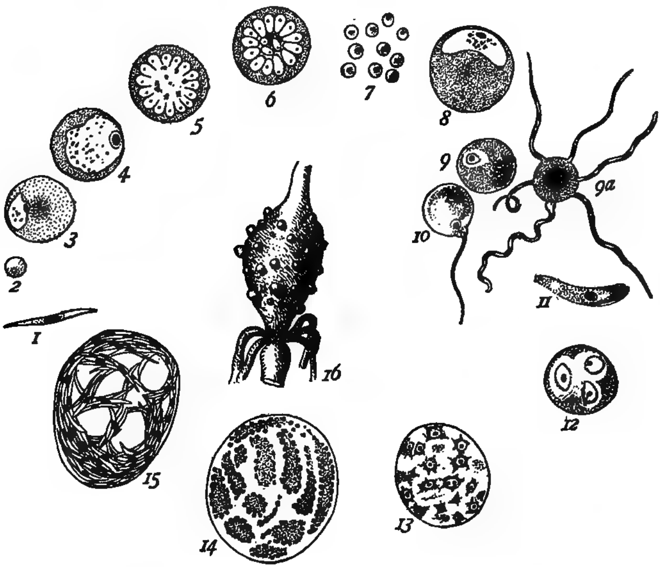


FIG. 69. Malarial organism.

2–7 show the stages that occur in ordinary blood, 7 representing the spores which appear after the blood corpuscle breaks to pieces. These spores are like 2 and immediately enter into fresh corpuscles, as at 3. 8 shows a so-called crescent body in the corpuscle. The crescent bodies become the sexual bodies, 9 and 9*a*, which develop in the mosquito. 10 shows the union of the female sex body, 9, with one of the flagella of 9*a*. 11–15 show the development of the united mass, 10, in the body of the mosquito, finally producing spores such as shown at 1. 16, the intestine of the mosquito, showing the malarial organism attached.

form of the parasites, however, requires three days to complete the cycle. The malarial parasites remain in the blood and never pass out of the body by any of the ordinary excretions. There is therefore no direct means by which they can pass from one person to another, and consequently malaria is not a contagious disease. This fact has been known for many years, and no instances of direct contagion have been noted.

The last few years, however, have disclosed the fact that there is a means by which malaria is transmitted indirectly from man to man, and have shown us how the

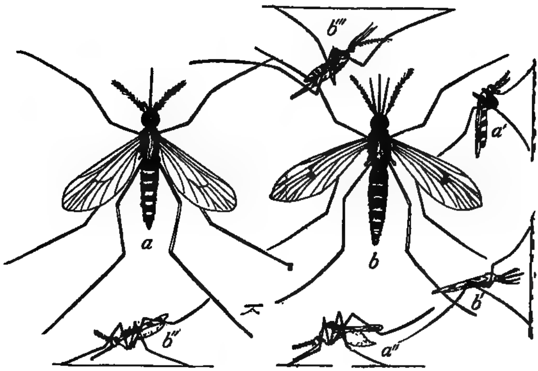


FIG. 70. *a*, the harmless mosquito (*Culex*); *b*, the malarial mosquito (*Anopheles*). *a'* and *a''* show the position of the harmless mosquito when lighting on the floor or on the wall; *b'*, *b''* and *b'''* show the position of Anopheles when lighting on the floor, wall, and ceiling.

human body usually becomes infected with this disease. A certain kind of mosquito (Fig. 70, *b*) forms an intermediate connection between a malarial patient and another individual. This kind of mosquito may bite the patient, sucking into its body at the time a considerable quantity of blood. Inasmuch as the blood contains the malaria parasites, the mosquito will become filled with them. The little organisms live in the mosquito as readily as they do in the human body, undergoing a different history, however. In the mosquito they pass through a new series of changes (Fig. 69, 8–15), finally lodging in the glands around the mouth (salivary glands). If this mosquito with its salivary glands thus loaded with these little parasites chances to bite another individual, thrusting its proboscis in through the skin, these parasites will pretty surely be forced into the body of that individual. When the mosquito flies away it will leave the blood of the one bitten inoculated with the parasites. They are now in a location adapted to their life and they begin to develop. In a few days they are abundant enough to produce a poisonous effect upon their victim and he develops an attack of malaria. Thus this particular disease is transmitted from person to person by means of one special kind of mosquito, and at the present time it seems as if all cases of malaria start originally from mosquito bites. Malaria is most prevalent at the seasons of the year when mosquitoes are abundant; it is most abundant in parts of the world where mosquitoes are most common; and it is most likely to be caught at night, the time when mosquitoes are the liveliest.

It should be noted, however, that not all kinds of mosquitoes are capable of carrying this malarial parasite. Fortunately the most common mosquito is quite free from them and is, therefore, not a source of danger. Only one group of mosquitoes is associated with this trouble. Fig. 70, *b*, shows the common form of this species, and also the ordinary, harmless mosquito, *a*. The differences between them are shown in the figures. The most easily distinguished differences are the *five* delicate hairlike feelers on the head of the dangerous species, rather than *three*, as in the harmless form (Fig. 70, *a* and *b*), and the method of lighting with the body held in a straight line (Fig. 70, *b′*, *b″*, *b‴*), rather than bent, as in the harmless species (Fig. 70, *a′* and *a″*). It must also be remembered that not all mosquitoes, even of the harmful species, will be dangerous. Only those that have sucked the blood from malarial patients will contain the parasites and be able to transmit the disease. In other words, of all the mosquitoes that may bite us in summer only a few are likely to be infected and produce any trouble. We may be bitten thousands of times and still be free from malaria, while the next mosquito that bites us may inoculate us with these parasites.

That family is the best protected against malaria that is the best protected against mosquitoes. If we live in a region where malaria abounds, it is somewhat dangerous to remain out of doors during the night, or even in the early part of the evening, unless properly protected. At this time mosquitoes are most likely to be flying about. From this fact arises the belief that night air is dangerous. It is not the night air that produces the trouble, but the mosquitoes in the air. It is also evident that the best method of protecting a household from malaria is by the use of screens. It is a curious fact that their use at our windows and doors is the best protection from these microscopic parasites, inasmuch as screens or mosquito nettings will keep mosquitoes from the houses and will reduce the chances of contagion. This is not a matter of theory only, for it has been found by careful observation and experiment that the simple procedure of covering doors and windows of houses with mosquito netting has produced a marked decrease in the amount of malaria in these dwellings.

It has been proved recently that *yellow fever* also is distributed by mosquitoes rather than by direct personal contagion. The species of mosquito is different from either of those shown in Fig. 70, and lives only in warm climates. Mosquito netting is the best check for this disease. Yellow fever has been almost wholly stamped out of Havana by simply surrounding the patients with netting, thus preventing the mosquitoes from biting them and becoming infected with the germs which they might carry to other persons. It has also been banished from the Panama Canal zone by draining the swamps and closing up the breeding places of mosquitoes; and the last time that yellow fever invaded the United States it was speedily crushed out as soon as active measures were taken to destroy mosquitoes and prevent their breeding.

In all truly contagious diseases the parasites have some means of leaving the body of the patient. Their methods of exit are numerous, but are not very difficult to determine in the case of any particular disease. Most types of contagious diseases have suggestive symptoms. For example, in smallpox, there is an eruption of the skin, and it becomes probable at once that this eruption is a means of elimination of microorganisms. In diphtheria (Fig. 71) the germs grow in the mouth, clinging to the surfaces inside the mouth and throat, and it is quite evident that the breath, or at all events the forcible breath that comes with coughing, will detach the bacteria from their position in the throat and blow them into the air. In the case of whooping cough the violent paroxysms of coughing are probably a means of eliminating

FIG. 71. Bacillus of diphtheria.

the infectious organisms. The same is true, probably, of measles, tonsilitis, and grippe. In consumption, infectious discharges from the lungs pass into the mouth and are voided in the sputum. It becomes evident, therefore, that here is a disease the contagion of which is found in the sputum and also in the breath exhaled when coughing. The ordinary breath does not contain the germs. In typhoid fever and cholera the most distinctive characteristic of the disease is the diarrheal discharges from the alimentary canal, and this suggests that the fæces may be the source of exit of infectious material. Thus, though contagious diseases differ very much from each other, it is rarely difficult to determine by observation the method by which the infectious matter leaves the body in the case of any particular contagious disease. The practical fact to bear in mind is that during the progress of an infectious disease any *unusual discharges* from the body, mouth, skin, or elsewhere are almost always the means of exit of the parasites, and from such excretions all members of a household should be most carefully guarded. Special attention should be given to the care of the various discharges from the patient, and if this is done the contagion may be reduced very largely, and in many cases be absolutely prevented.

FIG. 72. Mosquito that spreads yellow fever.

2. *How Disease Germs are carried to and fro*

There are several methods by which infection may be carried from the body of the patient to that of the healthy person. In the case of some diseases it is chiefly by direct contact. In such a disease as smallpox, where the infectious material is probably on the skin, contact with the patient would be very likely to infect a healthy individual. Hence, with all diseases of this character, isolation is rightly considered of the greatest importance (see page 269).

With many diseases, however, other means of transference are more common. The microörganisms are not able to travel of their own accord, and are always carried about by some other agencies, the chief of which are the following.

Insects. Insects are occasionally the means of carrying infectious material. The relation of the mosquito to malaria and yellow fever has been mentioned, and *flies* have a very close relation to the distribution of typhoid fever. So close is this relation that it is now urged that the name *typhoid fly* should be used. *Fleas*, also, distribute the bubonic plague, which has recently produced so many deaths in the Old World (Fig. 73). It is quite possible that insects may carry the infection of cholera and some other diseases; but we know little upon these matters at present. We are thus taught to avoid flies and lice, to shun mosquito bites and flea bites, and, in short, to avoid insects as much as possible. Mosquito netting has, therefore, an actual sanitary value.

FIG. 73. Bacillus of bubonic plague.

Larger Animals. Occasionally larger animals transmit infectious microörganisms. It is believed that diphtheria is sometimes carried from the patient in the sick room to another person by cats which wander at will about the house. The bubonic plague, which, fortunately, is as yet rare in this country but which is producing great ravages in Europe, Asia, and Africa, is known to be transmitted by fleas carried by rats. Tuberculosis is sometimes transmitted by cattle, through their milk, to children drinking it. There may be other instances, not so well known, where larger animals are the means of distributing infectious material.

Water. The distribution of disease germs by means of drinking water is chiefly confined to two diseases, *typhoid fever* and *Asiatic cholera.* Typhoid fever is very common and many epidemics are due to polluted drinking water. The disease is caused by a well-known bacillus (Fig. 74), and the method by which the water becomes contaminated is very easy to understand. The bacilli live in the intestines of the patient and are carried from him by the excreta. This material may be thrown upon the soil or into earth closets, and is liable in either case to percolate through the soil or be washed by rains into wells or streams. Wells are filled with water that has soaked through the soil, and are quite readily contaminated with typhoid germs.

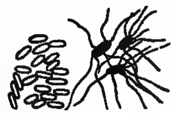


FIG. 74. Bacillus of typhoid fever.

Hence well water has been a very common source of the distribution of this disease. In most cities the excreta are thrown into sewers and the sewage may empty later into a river. Hence the drinking water of cities may sometimes present very great danger. Cities frequently depend upon the water of running streams, and nearly all streams of any size in civilized communities are more or less contaminated by sewage from houses or towns on their banks. Such water will be likely occasionally to become infected with typhoid bacilli; so that rivers and streams are positive sources of danger to communities that depend upon them for their drinking supplies. The result of drinking such contaminated water is the development of many cases of typhoid fever. A large part of the cases of this disease in cities are due to the contamination of drinking water. Many epidemics have been traced to just such a source.

The Asiatic cholera bacillus (Fig. 75) has also in recent years been shown to be distributed by means of the water supply. The practical result of this discovery has been that, since cities have learned to guard their water supplies, severe epidemics of cholera have been prevented. This subject, however, need not detain us, as the disease is hardly known in America. But in the event of a cholera epidemic it should be remembered that the majority of cases are due to drinking water that has been contaminated with cholera bacilli.

FIG. 75. Bacillus of cholera.

There are some other diseases occasionally distributed by water, but they are rare or little known. We need not consider them in our discussion.

The practical question how to avoid such dangers must face the head of every household. To answer this we must first fully realize that any water which has opportunity for sewage contamination is dangerous for drinking, and cities supplied only with water directly from rivers or streams have a supply that is frequently unsafe for use. Those cities, however, which have large reservoirs where the water stands for some time will have more reliable water, since the standing of water will in time always purify it of typhoid bacilli. The danger that the water supply may become a source of typhoid fever is, therefore, confined to those cities that use the water of running streams, or those that pour their sewage into a lake and then pump the water out for drinking purposes. The housewife in the city cannot control her water supply. This must be left to health boards and water commissions. But she should learn whether the water is from a source liable to be contaminated with sewage. If so, she must regard it as dangerous and bestir herself to treat it in some way that will make it safe for drinking. This can be easily done by simply boiling the water, since even a brief boiling destroys typhoid bacteria. This is a satisfactory method of rendering such water harmless. After boiling, the water may be cooled with ice and used for drinking.

Many households are supplied with various kinds of filters attached to their faucets for the purpose of purifying the water. Some of these are no more than strainers. They may make the water look clear and may remove some of the solid material; but, while it looks pure, such water is no safer after filtering than before. Filters in ordinary use have *no value whatsoever* in removing typhoid germs. They do remove large particles of dirt, but bacteria pass through them as easily as dust through mosquito netting; and though they make the water clear they do not make it a whit less dangerous.

One type of water filter (the Pasteur, the Berkefeld, and the Chamberland) is able to remove bacteria from water and thus remove all danger. Such a filter is shown in Fig. 76. The actual filter is a cylinder (Fig. 76, *a*) made of unbaked porcelain which is placed inside of a metal covering. The water enters the metal tube and is filtered through into the inside of the filter. These filters have been in use for several years and are quite efficient if properly cared for. But in the ordinary home they are apt to be worse than useless, since bacteria lodge in the porcelain filter and grow there, so that the water passing through will be actually contaminated in filtering. To prevent this requires more careful attention than will generally be given in a house. The filtering cylinder should be removed every day and carefully cleaned by a thorough brushing, and about every fourth day it should be sterilized by boiling in water for five minutes. This kills the bacteria in the pores of the filter and renders it safe for a few days. Unless one is willing to adopt this plan of regular sterilization of the filter, *it is better not to use it at all.* There is no other means in the household of filtering water which will remove from it the danger of distributing typhoid fever. There is a method by which the water supply of a whole city may be purified by filtering on a large scale; but this again must be left to the public officials, and is not within the reach of the housewife. Her sole method of purefying suspicious water is by boiling.

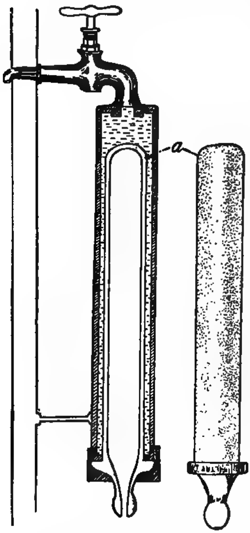


FIG. 76. Pasteur filter, showing the filter itself, *a*, made of unbaked porcelain, and the metal cover.

Aërated Waters. The recognition of danger connected with ordinary drinking water has led to the extension of the use of a variety of *aërated waters*, *Apollinaris water*, *Seltzer water*, etc. Such beverages are not bacteria free, and a study of a large variety has shown that occasionally the number of bacteria they contain is considerable. *Artificial* aëration, that is, charging the water with carbon dioxide, does not at once destroy germs, and if the water thus charged contained disease germs at the outset, the water is not rendered any safer than it was before aëration. Such artificially prepared waters, therefore, are, while fresh, no safer than the original water from which they are made. After they have stood for a few weeks the disease germs seem to die and the water becomes wholesome. The *naturally* aërated waters are, so far as known, never likely to be impregnated with disease germs. We may then conclude that naturally aërated water is safe from disease bacteria, and that other forms of aërated water are practically safe if they are not too fresh. In general, such waters are, therefore, more reliable than drinking water which has an opportunity for sewage contamination.

Ice. The question has been raised in the last few years whether ice made from sewage-contaminated water is safe to use for cooling drinking water. Typhoid bacilli are not killed by freezing, and it has been claimed, therefore, that such ice is as dangerous as water. A more careful study of the subject has shown, however, that although the bacilli are not killed by simple freezing, they are mostly rendered harmless if they remain frozen in ice for several weeks. Ice harvested in the winter is therefore safe to use the following summer. This statement applies to clear ice, but not to snow ice sometimes found on the surface of frozen ponds.

Milk. Milk is a means of distributing certain diseases; not, indeed, a vehicle by which a contagious disease in a household is carried from one member of the family to another, but rather a source by which diseases from outside may find entrance into the family. The diseases commonly attributable to milk are not very numerous, five of them being very definite specific diseases and one of a somewhat obscure type. The five definite diseases are *tuberculosis*, *diphtheria*, *scarlet fever*, *septic sore throat*, and *typhoid fever*. The other disease referred to is the indefinite series of intestinal troubles known as *summer complaint*, *summer diarrhœa*, *cholera infantum*, etc., all characterized by the presence of diarrhœa and particularly common in warm weather.

There is no doubt that all of these diseases are occasionally distributed by milk. The one most commonly attributed to this source is typhoid fever, and many instances have been recorded where epidemics of typhoid have been due directly to milk contaminated with typhoid-fever bacteria. Epidemics of diphtheria and scarlet fever have also been traced to the same source, though more rarely. The question whether any considerable amount of tuberculosis is attributable to milk has not been settled positively, but the probability seems to be that milk is a source of this disease, especially for young children. *Pure* milk, however, is never the cause of any of these troubles. Clean milk fresh from a healthy cow is never the source of any of the diseases above mentioned. Some cows have tuberculosis, and the milk of such a cow may be dangerous; diseased udders are believed to be sometimes the source of the bacteria which cause septic sore throat;

but cows probably do not have diphtheria, typhoid, or scarlet fever. Danger from these diseases lies in the possibility that between the time of milking and the time when it reaches the consumer the milk may have been contaminated with the bacteria which produce these troubles, and that these bacteria, growing in the milk, may render it a source of hidden danger.

The relation of milk bacteria to the production of summer complaint and similar diseases is not so well understood. The only points that we need notice are: (1) Such troubles are doubtless due to the bacteria present in the milk. (2) They are consequently much more likely to be associated with milk in summer than in winter, since bacteria grow much faster in warm than in cold weather. (3) Fresh milk which has been kept cool is less liable to produce such troubles than older milk which has been kept warm, partly, no doubt, because the latter contains more bacteria than the former. Practically, then, the housewife should remember that old milk that has been kept warm is a source of danger, and that occasionally even fresh milk may be the cause of the diseases above mentioned unless some precautions can be adopted.

How can precautions be taken in the household against these possible dangers? 1. We notice again that the milk that costs the most is the best and most reliable, while the cheapest milk is not only the poorest food but also the most dangerous. 2. Where it is possible to obtain information in regard to the character of the source of milk, the danger of contracting disease may be lessened. For in a small community knowledge concerning the man who delivers the milk should enable one to get some idea as to whether he is careful or careless in handling it. In general it is well not to buy milk from a dirty or careless milkman, for such a man is much more likely to sell milk that is a source of danger. For this reason milk distributed in glass bottles is more reliable than that distributed from metal cans. 3. Practically all of these dangers may be avoided by the use of pasteurized milk, Grade A milk, or certified milk. The latter are higher grades of milk, coming from special farms, and should have a proper certificate or an official grading. They cost more than the ordinary grade, but are safe, and may be given to infants without fear of contagious diseases. In general, then, the first factor to be considered in guarding the family from disease through milk is the obtaining of the supply from reliable sources only, even though the price may be higher. This will give a more reliable product, one that is more valuable as a food and less liable to produce disease.

But in many households this may not be possible, and the family may be obliged to depend upon the ordinary milk supply without any knowledge of its source. What should be done under these circumstances? Such milk can be rendered harmless, so far as concerns the diseases referred to, by the processes of pasteurization mentioned on another page. Since milk from an unknown source may be rendered safe for use in this way, it is easy to understand why pasteurization has in recent years come to be so widely adopted. The same end is less satisfactorily reached by boiling.

Every housekeeper will ask, however, whether such a precaution is necessary under ordinary conditions. This general question cannot be answered and it will always be a matter for individual decision. That there is some danger is certain. Whether the danger is sufficient to warrant or demand the pasteurization of *all* ordinary market milk is a matter of opinion upon which bacteriologists are not yet agreed. For young children who must be fed upon cow's milk it is, under the conditions of modern life, not safe to use the ordinary milk supply. Many children are brought up on such milk without suffering materially therefrom; but if it is used with young children there is considerable danger of the diseases mentioned, especially diarrheal troubles. In feeding young children, therefore, it is wise, and almost necessary, to adopt some method, preferably pasteurization, of destroying the disease germs that may be present. If the milk is to be used by adults, the necessity is not so great, for adults are not as a rule so liable to diseases from this source. Nevertheless milk from the common milk supply, unless pasteurized, must be looked upon as a possible source of typhoid fever and some other troubles. It should be emphasized especially that milk is not necessarily harmless because it has not soured. It is true that soured milk contains more bacteria than sweet milk, but most of them are harmless, while a sample of milk that is perfectly sweet may contain disease bacteria and be unsafe to use.

The Air. The readiness with which bacteria can float in the air suggests that they may be easily distributed by this means. The agency of air in distributing diseases has been somewhat overrated, but it occurs in a few diseases which we usually look upon as extremely contagious. To guard against diseases distributed by the air is particularly difficult. Fortunately this is not a common method of distribution, for all recent experience tends to show that it is rare and that the danger is confined to the immediate vicinity of the patient. The germs given off from him soon settle to the floor, and as a rule live only a short time. *Measles*, *scarlet fever*, and *smallpox* may be thus distributed, and a person may take them without coming in actual contact with the patient, when no other means of infection is known save that of air currents. The distribution of disease bacteria by means of air, however, does not extend very far from the patient. It is, in fact, questioned to-day whether air plays an important part in the distribution of even these diseases. It was once blamed in the case of almost any disease whose distribution seemed mysterious. If, however, we stop to realize how easy it is to come into indirect contact with a patient through articles contaminated with his discharges, it is doubtful whether one need take the air into account at all as an agent of dissemination. If, moreover, bacteria are thrown off into the air by a patient they must rapidly settle to the floor, and the danger of taking such disease decreases rapidly as we pass from the immediate vicinity of the patient.

From these facts we can conceive that the dust and dirt collecting on the floor of the sick room may become a source of trouble. The dust that accumulates on the floors, walls, window sills, or doors, or on any article of furniture in the room occupied by a patient is likely to contain the living disease bacteria. Such material is therefore a source of contagion, and in protecting a family from attacks of contagious diseases the dust accumulations of the sick room must be looked upon as a special source of danger.

In a few diseases characterized by *coughing* the germs are distributed by air from the mouths of the patients. The most noticeable of these are *consumption* (Fig. 77), *whooping cough*, and very likely *measles* at certain stages. The air coughed from the mouth in these cases contains small particles of moisture which float around for some time, and these particles are likely to be laden with disease germs. As long as this water is floating the air may be dangerous to another person breathing it. In these cases also the danger is practically confined to the immediate vicinity of the patients, for these particles of moisture do not float very long but soon sink to the ground or come in contact with the walls of the room. Danger is confined to within a few feet of the patient, a distance as great as that of the next room being usually sufficient to free the air from such floating microörganisms. The only way to avoid such dangers is to insist upon plenty of fresh air in the sick room, and to air the rest of the house frequently and thoroughly.

FIG. 77. Bacillus of tuberculosis.

Tuberculosis (Fig. 77), or consumption, has a special source of danger in the sputum of the patient. This material is filled with the dangerous bacilli. As long as it is kept moist they have little chance of distribution; but if the sputum is voided on the floor or where it can dry, the dried material will blow around as dust, still containing active bacilli. The sputum of consumptive patients should be received in old cloths which can be burned, thus destroying all danger, or in special cups which can be sterilized by disinfectants.

It is extremely important, also, to remember the significance of dust in a schoolroom. A schoolroom with children from many homes is likely to be a collecting place of disease germs. The children frequently bring such germs to the schoolroom, where they are distributed through the air, float around for a while, and eventually settle on the floor. If they remained on the floor they would be harmless, but every time the room is swept or dusted the germs are stirred up again. Sweeping and dusting a schoolroom decidedly increases the danger of contagion. If feather dusters and brooms could be discarded, their places being taken by damp cloths and vacuum cleaners, the amount of contagion would be materially reduced. If the floors, window sills, desks, and tables were wiped each day, the dust, instead of being scattered through the room, would be collected and removed by the damp cloth. The cloth should subsequently be rinsed and occasionally washed in hot water. Where this method has been adopted the results have been surprising. One school, for example, with over four hundred pupils, burned up the feather dusters and used damp cloths for cleaning. During the following year there was not a single case of contagious disease among the scholars, an altogether new experience for the school. The same general facts would apply equally well to the household. Brooms and dusters simply distribute germs through the air, and should be dispensed with as far as possible. Vacuum cleaners and damp cloths should, where possible, take the place of brooms and dusters. Woodwork should always be cleaned with a damp cloth rather than by dusting. No simple rule will be more useful in checking the distribution of contagious diseases than that of discarding the old-fashioned method of dusting and replacing the same with the more sanitary one of wiping. It is much better to have bacteria in the carpets, where they will die after a time, than to have them in the air that we breathe.

Uncooked Food. Some of the foods that come upon our tables without cooking may be the means of distributing disease. This is not, however, very common, and is mentioned only as a possibility. If fruit has a chance to become contaminated with infectious material (such as sewage, or sewage-infected water, or consumptive sputum), and is eaten uncooked, the person eating it is in danger of contracting disease. The chance, however, of fruit becoming contaminated with disease germs is not very great, and we cannot therefore look upon it as a very serious source of danger in a household. Lettuce, celery, or radishes grown on sewage farms have a chance of contamination from typhoid germs in the sewage used for fertilizing the soil, and have been pointed out as possible dangers. Troubles from these sources are, however, rare and may be commonly neglected, but in times of epidemics it is always wise to guard against even this possible source of danger by avoiding the consumption of fruit or vegetables that have in any way whatever been exposed to a chance of contamination.

Although it is thus seen that quite a number of our foods are sources of possible danger, it is not wise to be too fearful over the matter. The fact that certain diseases under certain conditions are caused by some of our commonly consumed foods must be admitted; but it must also be remembered that the chances in each case are small; that our fathers and grandfathers have consumed similar foods for generations and have suffered only occasionally therefrom. It is therefore wiser not to be overalarmed or to make life burdensome by too great precautions, but simply to use such care as may seem feasible and possible in our homes, and not give up the use of any desirable food because we know that it may be an occasional source of danger. Some people have actually given up the use of butter and milk because it has been shown that they contain so many bacteria. Such a procedure is sheer nonsense. The facts here outlined have been given not for the purpose of inducing people to avoid the use of such materials, but merely to suggest to them the wisdom of adopting possible precautions against consuming contaminated foods.

Bacillus Carriers. It frequently happens that persons who have had germ diseases continue for some time after recovery to carry around in their bodies the bacteria of the disease. Although the germs no longer do any harm to the recovered patient, they are still as dangerous as ever if by any chance they should reach another individual. Such persons are called "bacillus carriers," and as long as they continue to harbor these disease germs they are a source of danger to their associates. Such bacillus carriers are particularly common after cases of typhoid fever and diphtheria. Recovered typhoid patients have been known to carry active typhoid bacilli for many years. In one famous case such a person was employed as a cook, and for a period of twelve years cases of typhoid fever appeared in all families shortly after she was first employed by them as cook. Such bacillus carriers in a dairy have also been known to infect the milk and produce a typhoid epidemic, distributed by the milk supply. Even more common is the distribution of diphtheria by carriers. While the diphtheria germs do not remain in the patient's mouth for any such length of time as those of typhoid fever linger in the body, they do remain there from three to six weeks, and sometimes for some months. As long as they are present the person is a source of danger to his associates. A person may become a carrier of diphtheria germs who has not himself had the disease. It frequently happens in a school that after one or two cases of diphtheria have appeared, quite a number of the children will be found to have diphtheria germs in their throats, having obtained them, doubtless, from associating with the patients. To these carriers the bacilli may not be doing injury, since some children are immune; but as long as the germs are present in their mouths the carriers are a source of danger to others who may not be immune. The most efficient method of preventing the distribution of this disease through a school, or any institution, is to examine the throats of all children who are associated with cases of true diphtheria, and then temporarily to isolate those whom a microscopic examination shows to be carriers. By such means it is practically always possible to check the spread of diphtheria and to prevent epidemics in schools, and the method is more effective than that of closing the schools.

Against some diseases we do not yet know how to protect ourselves. The best known of these is *infantile paralysis*, the method of its distribution not being positively known. It is certainly distributed by people either directly or indirectly, and the wise precaution is to keep away from patients or from those who have been in contact with them.

One thing to remember in the spread of disease, whether from bacillus carriers or from active cases, is the ease with which our usual habits allow us to contaminate our hands with saliva or nasal discharges and then to transfer this contamination to others. Many sanitarians insist that this is the most important form of direct contagion, and that if we could all manage to keep our hands away from mouth and nose, the spread of disease would be reduced to a minimum. Unfortunately, however, in the case of a head cold, when the danger of infection is greatest, it is almost impossible to avoid thus contaminating the hands. We should, nevertheless, learn to regard our hands as contaminated at such times and should be careful not to handle food or to touch other people (as in shaking hands) without first washing our hands.

3. *Means of Invasion*

A matter of almost equal importance in considering the distribution of disease is the means by which the bacteria get into the body. Each species may have its own means of entering, and frequently each can find entrance in only one way. If it should get in by other means it would produce no injury. Some species, however (tuberculosis), produce trouble, no matter how or where they enter. If we know the means of entrance of any contagious material, we are of course in a much better position to guard ourselves against it. The important means of entrance are as follows.

The Skin. Some diseases find entrance chiefly through the skin. This is true of the bacteria which cause the many little sores, festers, boils, and abscesses, all of which are commonly due to bacteria entering through the skin (Fig. 78). These bacteria are harmless in the stomach, and, indeed, we are swallowing them all the time. The mouth contains great numbers of these bacteria, as well as numerous other species, but they do us no injury. Skin diseases like *ringworm*, *favus*, etc., enter in the same way. This is likewise the case with *lockjaw* (Fig. 79), *erysipelas* (Fig. 78, *b*), and various forms of blood poisoning, some of which are of comparatively little importance, while others may be serious and fatal. It is possibly also true of some other diseases; in some cases we have really no knowledge of the matter.

FIG. 78. Various pathogenic cocci. *a*, pus cocci; *b*, cocci producing pneumonia; *c*, erysipelas cocci.

But though these diseases enter through the skin, it should be remembered that the surface of the body is commonly quite well protected against the invasion of microörganisms. We have already seen that the skin of fruits, if uninjured, protects the softer portion of the interior from decay to a considerable extent, and that the organisms which produce decay usually enter through bruises, cracks, or cuts in the skin. Precisely the same thing is true, probably to an even greater extent, in the case of the human body. The outer layer of the skin is a protection which the bacteria cannot ordinarily penetrate. If therefore the skin is unbroken and uninjured, a person is almost perfectly protected against the

FIG. 79. Bacillus of tetanus

invasion of the particular kinds of bacteria which pass in through the skin. A person whose skin is not broken can without danger handle infectious material which might produce fatal results were the skin cut or bruised. It is, however, hardly ever the case that a person's skin is unbroken over his entire body. Cuts, bruises, and scratches break the skin, and through such openings microörganisms may find entrance into the body. A little sliver in the skin is frequently the starting point of a fester, a boil, or an abscess, or even of a severe and perhaps fatal case of blood poisoning. So small a thing as a pin prick may sometimes allow entrance to mischievous bacteria.

The conclusion of all this is that a whole skin is a protection which can almost absolutely be relied upon; but a more important lesson is that any break in the skin should be more or less carefully protected. The almost surely fatal disease *lockjaw* (*tetanus*) comes from soil bacteria getting into the body through the skin, and is apt to occur in wounds made by rusty nails, etc., which have been lying a long time on the earth and have become contaminated with the lockjaw bacillus. All cuts and bruises should be carefully washed and treated with tincture of iodine. The fear of bacteria explains why the surgeon endeavors to clean the surfaces of wounds by some disinfectant which will prevent the growth of microorganisms. Here, too, is the reason for protecting from further contamination a wound thus cleansed, by covering with bandage or plaster. All of these devices are for the purpose of protecting the body from the entrance of bacteria, and make it possible for the wound to heal readily without the disturbance which would be produced if bacteria got into the wound. Modern surgery is based on the simple plan of keeping bacteria out of wounds. The frequent efficacy of treating wounds by such crude methods as covering them with tobacco juice or even mud is due to the fact that these act as mild antiseptics and protect wound surfaces from the entrance of dangerous organisms.

The skin should therefore be carefully guarded, and in all cases of diseases connected with the skin, a list of which has been given above, special care should be taken that no part of the body which is cut or bruised or scratched, or has sores upon the surface, should be allowed to come in contact with infectious material. If this is done, the danger of contagion will be greatly reduced. Though a person with whole skin may safely handle infectious material, no matter how dangerous it is, one whose hands contain even the smallest pin scratch might contract contagion and suffer illness or death from such procedure.

The Mouth. Some diseases find entrance through the mouth by means of the food or drink swallowed. They are chiefly *typhoid fever*, *tuberculosis*, *diphtheria*, and *cholera*, although there are some others. It is manifest that not only is the chance of contagion through the mouth less than when a disease is borne by air currents and enters through the skin, but it is more easily prevented. The diseases mentioned are not usually regarded as very contagious, except in the case of diphtheria, where the contagion may be through food (milk) or air. To prevent contagion from most of these diseases it is only necessary to guard all that enters the mouth, keeping it free from infection.

Food served hot is free from danger. Food and liquids should be specially guarded from contamination in the sick room, especially in cases of typhoid fever. The utensils used by the sick patient should never be used by other inmates of the house. Those who have anything to do with nursing the patient or handling soiled bedding should be especially careful that nothing has an opportunity of getting into their mouths. Especial care is needed to guard school children in these respects, for their ignorance and thoughtlessness lead to many chances of contagion from mouth to mouth. Contagion in these diseases may be carried by the fingers; for if a person touches the patient he is likely to have his fingers contaminated with infectious material, and should he subsequently place his fingers in his mouth, infection would be very likely to follow. If one guards everything that goes into the mouth, the chance of infection is slight. It is a significant fact that in cases of typhoid and cholera — the most typical diseases of this sort — nurses and doctors rarely take the disease from their patients. They have learned the method of infection, and guard themselves by keeping infectious material from their mouths.

Breathing. Some diseases undoubtedly enter the body with the breath. Fortunately the diseases thus contracted are few. Foremost among them stands *tuberculosis*. *Diphtheria* is probably contracted in the same way, and possibly the *grippe*, *whooping cough*, and *measles*, although in regard to the last two we know almost nothing. There is no means of protecting ourselves against this method of infection except to keep away from individuals suffering from the diseases. As already mentioned, the bacteria that pass into the air fill the space in the immediate vicinity of the patient, but do not disseminate themselves to a very great distance. Hence persons near the patient are exposed to the disease by breathing the air, while those at some distance are but slightly exposed, and those at a greater distance, not at all. The danger is mostly confined to the room in which the patient is kept, and hardly extends to the rest of the household. The only protection against this method of invasion, then, is to avoid the immediate vicinity of the patient, and to keep the air of the room and the rest of the house as fresh as possible. If one who is obliged to breathe such air will take the opportunity frequently to breathe fresh air out of doors, his danger will be reduced.

Summary

It is plain, then, that there are various facts the housewife should know in order to help prevent the distribution of contagious diseases. It is especially important to remember that no contagion can take place unless three conditions are fulfilled: (1) the disease germs must be eliminated from the patient's body; (2) they must be carried to a healthy individual; and (3) they must have some means of invading the second individual. If this chain of events is broken at any point, the spread of the disease can be prevented.

Realizing this, it is well to remember the important means of elimination, of carriage, and of invasion. Elimination may take place through saliva or body discharges (especially from nose and throat), through forcible breathing (such as coughing), and through skin eruptions. With disease germs that cannot infect a new human being directly, exit may be brought about by the bite of an insect. Carriage from one individual to another may take place through other animals, especially insects, through water, ice, milk, uncooked vegetables, or sometimes by direct contact of one person with another. Sometimes diseases are also spread through "carriers," healthy individuals who harbor the germs and can transmit them to others without being sick themselves. Some diseases are spread by one of these means, others by different ones; and in the case of an epidemic it is important to know the exact facts, so that one may be on his guard against the true channel of infection and not be afraid of others. Invasion of a new host may occur through a broken skin (rarely through an uninjured skin), through the mouth, or through the respiratory tract. Here again each disease has its own method of entrance, and in the fight against it its peculiarities should be taken into account. With an intelligent understanding of these factors a housewife can do much toward keeping her family in good health.

CHAPTER XVIII

PRACTICAL SUGGESTIONS

From the facts outlined it is very easy to draw certain practical suggestions for dealing with contagious diseases.

Isolation. In the case of highly contagious diseases, such as scarlet fever, measles, smallpox, etc., the patient must be isolated from the rest of the household as completely as possible. This should be done by confining him to one room and allowing no one to enter except those necessarily engaged in caring for him.

The same general treatment may be applied in diseases characterized by coughing, like whooping cough and consumption. Diphtheria, also, though not distinctly a coughing disease, is distributed by breath that is forcibly exhaled by the patient, and the seriousness of the disease makes it necessary to adopt isolation. While it is manifest that the only means of absolutely avoiding contagion from tuberculosis and whooping cough is to isolate the patient, it is also clear that complete isolation of a sufferer from whooping cough or tuberculosis is rarely possible in an ordinary household. Diphtheria is such a serious disease, so rapidly fatal, and its course is usually so brief, that complete isolation is not only feasible but necessary. The other two diseases last so long that isolation is generally very burdensome, difficult, or impossible. It is well to remember that in such diseases periods of coughing are the times when there is most chance of contagion, and that all well persons should, so far as possible, be kept away from the vicinity of these patients at the time of coughing. If this is done and the sputum is cared for, the chance of contagion is much reduced.

The question often arises how long the isolation should be continued. One must usually depend upon the physician or board of health for an answer to this question, since the period of isolation varies with different diseases. For scarlet fever it is about six weeks; for whooping cough it is certainly as long; for diphtheria the time of necessary isolation varies from two to six weeks, and a laboratory examination is necessary to determine when a convalescent patient ceases to be able to transmit the disease to other children. Measles is only contagious in its early stages, and a week after the patient "breaks out" is no longer communicable. In general, the period of isolation must be determined for each disease by the advice of physician or board of health.

Excreta. In the case of diseases located in the alimentary canal, and distributed by excreta, isolation of the patient is not so necessary, but everything that comes in contact with the discharges from the alimentary canal should be carefully guarded. This will include not only the discharges from the intestine but also those from the mouth. All possible precautions should be taken to prevent any such material from being distributed through the household. Such diseases can very easily be confined to the patient and the sick room if care be taken with the excreta, if all soiled materials coming in contact with the patient and all eating utensils be thoroughly disinfected by placing them for ten minutes in boiling water.

Clothing and Bedding. Any articles of clothing that come in contact with a patient, any towels or cloths used in bathing him, are very likely to be mediums for the distribution of disease. If it is a skin disease, the clothing is sure to become infected. If the disease bacteria are eliminated through the sputum or the excrement, it is almost inevitable that the clothing, especially the bedding, will be contaminated with infectious material. In all skin diseases, as well as in cases of typhoid, diphtheria, tuberculosis, and indeed most contagious diseases, clothing and bedding are sources of infection and must be guarded carefully. The clothing and bedding should not be sent to the general laundry but washed separately and thoroughly boiled. Nothing should be worn in the sick room by nurse or patient that cannot be washed, and all unwashable fabrics, curtains, carpets, etc., should be removed from the room where there is a contagious disease.

Eating Utensils, etc. The eating utensils used by a patient, or indeed anything that he handles or uses during his sickness, may be very easily contaminated with the infectious material. It is perfectly evident that a diphtheria patient who has the bacilli in his mouth will contaminate the spoons, knives, and forks which he uses with the bacteria that are producing the trouble in his throat. The same thing would be true, though perhaps to a less extent, of all contagious diseases, for a patient cannot handle anything without danger of thus infecting it. Consequently all utensils from the sick room and all articles handled by the patient must be looked upon as means of distributing the disease. The practice of taking the spoons, knives, cups, and plates from which the patient has taken his meals, and carrying them into the kitchen to be washed with the other household utensils for subsequent use by the rest of the family, is a dangerous one and is one of the easiest and perhaps most common means of distributing the disease from the sick room to the rest of the household. Doubtless many times the distribution of diseases is attributable to the indiscriminate use of the same eating utensils by the family. It is easy to avoid this danger. (1) Allow no one to use the eating utensils which the patient has during his sickness. (2) After his recovery put them into boiling water and leave them for several minutes. Do not wash them with the eating utensils of the rest of the household. Thorough boiling will render them harmless, and therefore even a knife or a spoon coming from the sick room should be placed in boiling water before it is used by any other person. It must be borne in mind that water that is simply hot is not sufficient for this purpose. The water must be *boiling*, and it is better if the articles are placed in the water and the water boiled for five or ten minutes before they are taken out to be used. The statements made concerning eating utensils apply also to any articles handled by the patient.

Books used by children recovering from diphtheria or scarlet fever and then returned to a public library may distribute disease through a community. In cities where the schools furnish supplies children should be cautioned against putting into their mouths pencils, etc., particularly those belonging to other children. If a person has a scalp disease, like ringworm, he should not be allowed to use combs or brushes used by other members of the family, for other cases of the disease would be sure to follow.

Nurses. Those who nurse the patient should take special care in a number of directions. They should have a change of clothing to put on when they leave the sick room to mingle with the rest in the house; they should wash their hands frequently with some disinfectant to be mentioned later, especially after handling the patient, his bedding or his clothes. They should be especially careful to avoid putting their fingers into their mouths, for in many diseases this is a common means of infection. A nurse who carefully observes these precautions is much less liable to infection from any of the diseases. The face also requires frequent washing. The hair is a particularly good lodging place for bacteria, and a good nurse wears a cap to protect her head in cases of contagious diseases.

Treatment of the Sick Room. After the recovery of the patient it is necessary that the room he has occupied should be thoroughly disinfected before any other members of the household are allowed to enter it. The method of disinfection will be found in another place. We will here only emphasize the fact that in order to prevent the appearance of other cases of the disease such disinfection is absolutely necessary before the room is occupied by other people.

The treatment after recovery from a contagious disease is sometimes difficult to determine. So far as concerns the patient himself, the proper procedure after recovery is to bathe himself thoroughly in a disinfectant solution suitable for this purpose, the disinfection or bathing including the hair as well as the rest of the body. The person should be given clean clothes that have not only been thoroughly washed but disinfected by proper means; after which there is no danger of his transmitting the disease to others.

Sewage. Since the discharges from patients find their way into sewage, this material is extremely dangerous, indeed from the standpoint of human health one of the most dangerous of all substances. Every effort should be made in the household to guard against it. Particular attention should be given to keeping the drinking-water supply from becoming contaminated with sewage. In cases where the water is from a well there should be especial precautions against contamination from privies or sewage. The health of the family depends upon having the well a long distance from sewage and privies.

In cities the sewage empties commonly into one general system, and most of the houses are connected by a series of underground channels. These sewers carry the discharges from all the patients in the city, and hence contain the dangerous disease germs. Since each house is connected with this system of sewerage, it is of the greatest importance in modern cities that the connections with the sewer pipes should be most carefully guarded. Proper plumbing of the approved type does this satisfactorily. All bowls, sinks, and closets should be connected with the sewer by traps. The general design of such a trap is shown in Fig. 80. Between the bowl or sink and the sewer is a bent tube filled with water. As long as this trap is thoroughly filled with water no bacteria and no gas can pass from the sewer into the sink.

To be efficient a trap should remain full of water. The traps, however, occasionally get emptied of water, and then gases may pass up from the sewers. Such gases are offensive in odor and used to be regarded as dangerous to health. It is now realized that these gases do not bring bacteria into the house with them and hence are harmless although undesirable. The insides of the traps, however, become breeding places for certain kinds of bacteria, though rarely disease bacteria, and may in time become full of them. It is therefore desirable to pour some kind of disinfectant occasionally into the bowls and sinks. A weak solution of carbolic acid, one part to twenty, or a solution of chloride of lime, one part to twelve, put into bowls and sinks will disinfect the traps. It is also an excellent plan to pour boiling water frequently down sinks, bowls, and closets, for this not only helps to clean but helps also to disinfect.

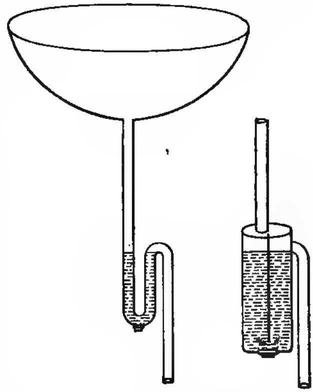


FIG. 80. Diagram showing the principle of two kinds of traps separating washbowls from sewers.

Leaky sewer pipes in a house are a serious menace. If these are poorly laid, the contents of the sewer may ooze out into the cellar or soil under the cellar and become a source of considerable danger. For this reason it is desirable to have sewer pipes laid where they may be easily inspected. When the pipes are laid above the cellar floor, leaks are more likely to be noticed and to receive attention at once.

Where sewage leaks, flies are sure to gather, and disease may be carried by them even to people outside the immediate household. The evils from sewer *gas* have, however, been overrated. Sewer gas itself is not capable of producing any specific disease. At one time it was thought that sewer gas was a great menace and likely to produce various diseases in those breathing it. Further experience has shown that this is not true. The gas is unpleasant but not in itself harmful. The diseases are caused not by gases but by living bacteria, and sewer gas can never produce disease.

Protection following Cure; Immunity. The recovery from a contagious disease, as a rule, protects the individual more or less perfectly from a second attack of the same disease. But the amount of protection differs with different diseases. After recovery from some of our contagious diseases, like scarlet fever, a person rarely has a second attack during life. With other diseases a second attack is more likely to follow, but in all cases there is at least a temporary protection following the recovery. In other words, after a person has recovered from a contagious disease he is not, at least for some time, liable to the same disease again. This protection lasts in some cases for many years and perhaps through life; in other cases it may last only a few years; in some cases perhaps only a few months or weeks; but a temporary protection is always gained. The reason why one is thus protected from a second attack scientists have not yet wholly explained, but its practical importance is beyond question.

Vaccination. A word must be given in regard to the method of protecting the body against smallpox known as vaccination. This method has been in use over a hundred years, but there is a vast deal of misunderstanding in regard to it. The fact of the case is that vaccination gives to the individual a certain amount of protection against the dreaded and frequently fatal disease, the protection being due to about the same cause as that which produces the immunity following recovery from germ diseases. The protection is not an absolute one, since vaccinated persons do occasionally take the disease. But for a time after vaccination one is almost surely protected against smallpox. How long this protection may last no one knows. It certainly does not last forever, and if one wishes to remain immune it is necessary to repeat the vaccination occasionally. For a year or two after vaccination the protection is strong and nearly absolute. But after a couple of years it gradually becomes reduced, and after ten or fifteen years the amount of protection afforded is very slight. The proper method, therefore, of guarding against smallpox is vaccination in childhood, followed by vaccination some years later, and perhaps again at intervals in later life. Experience has shown over and over again that proper attention to vaccination will check smallpox epidemics, and no other means has hitherto been satisfactory.

It must be recognized, however, that vaccination is not always harmless. In the vast majority of cases the person suffers nothing except a very trifling inconvenience from the treatment. In extremely rare cases, perhaps, more serious results arise. If these secondary troubles do occur, they are usually not due directly to the vaccination but to the vaccination wound becoming contaminated with bacteria. It is therefore necessary to protect the wound carefully against possible contamination. This is done by the physician in various ways. Although there is thus some danger in vaccination, the chances of trouble are very slight indeed, whereas the protection afforded against smallpox is so great as to lead scientific men and physicians to recommend its use unhesitatingly as a general protection against this extremely violent and frequently fatal disease.

Modern physicians have two splendid weapons in fighting diphtheria, one a cure, the other a preventive. The cure is **diphtheria antitoxin**, a preparation that has been known since a little before the beginning of this century. If it is injected into the patient sufficiently early in the disease, it is an almost certain cure. The preventive is **toxin-antitoxin**, a mixture of antitoxin with the toxin (i.e. poison) produced by the diphtheria bacilli. If a child is treated with this mixture under proper conditions, he is protected against diphtheria many years, perhaps for life. The use of these two products is being adopted very widely by physicians, and every housewife should understand that it is a precautionary measure that is perfectly safe, and the only known means of protecting a family where complete isolation of a diphtheria patient is impossible.

A method of vaccinating against typhoid fever has also been devised and is coming to be extensively used. The treatment is perfectly harmless, and it gives a very high degree of protection against the disease. It is so efficient that since 1914 it has effectually protected the armies of the world from typhoid fever, the disease that previously devastated army camps. This anti-typhoid vaccination is becoming more and more common among people at large as well as in armies, and is a wise precaution to all. The protection does not last more than two or three years.

Physical Vigor a Protection against Contagion

The best protection against contagion is robust health. A person in strong, vigorous health is much less liable to yield to disease than one less robust. Consequently in the attempt to protect the household from contagious diseases special emphasis should be placed upon methods of increasing the physical vigor of its members. This can be done by wholesome food, by exercise, and by fresh air. An active body is far less liable to disease than one more or less passive. The need of fresh air should be emphasized, perhaps, more than any other point, for the air in houses, for reasons already indicated, is much more liable to be filled with infectious material than the outdoor air, and a person who constantly remains in the house is much more liable to yield to contagion. If, however, he is careful to exercise in the open air, he will ward off attacks to which otherwise he might yield. This applies even more forcibly to the air of our sleeping rooms than to that of our living rooms, for fresh air in the sleeping room is one of the greatest desiderata in maintaining good health. The belief that night air is injurious is responsible for much ill health. Sleeping in close rooms without sufficient air causes a general lowering of bodily vigor. Our sleeping rooms should have the windows open even in cold weather, and, provided there be mosquito nettings at the windows to keep out insects, there is absolutely nothing to be feared in night air. While vigorous health is a protection against some diseases (tuberculosis), it is far less efficient against others (smallpox).

It should always be borne in mind that contagious diseases are real things, and not the result of imagination. They are produced in our bodies by the growth of certain microscopic animals and plants in our blood, muscles, or elsewhere. They cannot be warded off by simply disbelieving in their existence, and the sooner the housewife learns that a contagious disease is due to distinct living beings which are transported from one person to another and live as parasites in the patient, the sooner will she be in a position to protect her family from the spread of contagion.

General Conclusions

Each type of infectious disease must be fought in its own way. The so-called children's diseases are so decidedly contagious that isolation alone is capable of preventing their distribution. Of the adult diseases, however, the most serious may be largely checked by proper means. Smallpox must be fought with vaccination and isolation; diphtheria by antitoxin and isolation; typhoid fever by vaccination, by a guard placed over the water and the milk supplies, and by fighting flies; malaria by destroying the breeding places of mosquitoes and protecting the body from mosquito bites.

Of all diseases, however, tuberculosis is most widespread and demands most attention. The common form of this disease is *consumption*, but the bacteria may attack other parts of the body, producing other diseases, such as *scrofula*, *hip disease*, etc. Consumption must be guarded against by destroying the sputum of patients and avoiding their breath while coughing; and in any form of the disease that produces open sores, the discharges from such sores must be carefully destroyed. In spite of the long-accepted belief, consumption is not hereditary, but is contagious. Its spread through families is due to the close association of patients with the other members of the family. It is a disease associated with small rooms, poor ventilation, and crowded houses where the healthy members of the family live with consumptive patients and frequently sleep with them. Under such conditions contagion is almost sure, and the disease spreads from person to person just as decay spreads from apple to apple in a barrel. More air, more light, more care of the sputum and other discharges, greater attention given to guarding against the coughing of the patient, as for example inducing him to cough into cloths that can be burned, — these are the remedies against the spread of the contagion, and strict attention to these facts would soon convince any one that the disease is not hereditary but due to infectious matter disseminated from the patient. The child of a consumptive mother may even nurse at his mother's breast with little danger of contagion; but sleeping with her and breathing her breath while she is coughing is very likely to give him the disease and lead to the erroneous belief that he inherited it from his mother.

General Rules

There are a few simple rules whose observance will reduce the chances of contagion. These rules should be followed by all, but it is particularly important that children in every household, and especially children in schools, should be taught their significance. The most important rules are:

Do not spit on the floor.

Do not put the fingers in the mouth.

Do not wet the fingers in the mouth for the purpose of turning the leaves of books, especially library books, inasmuch as book leaves are sometimes the lurking places of disease bacteria.

Do not put pencils in the mouth.

Do not put money in the mouth. This is extremely important, because money is liable to come in contact with all sorts of people and to become contaminated with many kinds of disease bacteria.

Do not put into the mouth anything that another person has had in his mouth. This refers to gum, apple cores, candy, whistles, bean blowers, drinking cups, etc.

Turn the face aside from others when coughing. This will sometimes prevent contagion passing from one person to another, inasmuch as the breath in coughing distributes disease germs.

Be always particular about personal cleanliness, frequently washing the face and hands.

CHAPTER XIX

DISINFECTION

In every household the problem of disinfection is sure to arise in connection with contagious diseases, and it is a question of more or less serious import according to the seriousness of the disease and the number of inmates in the house. The purpose of all disinfection is to prevent the spread of contagious diseases from one person to another. Hence it is desired to destroy the microörganisms which cause the disease. If this can be done there will be no chance of contagion, but until it is done there is always a possibility that a healthy person may contract disease by coming in contact with the germs.

In connection with the treatment of infected material two terms are frequently confused. An *antiseptic* is a material or a treatment which checks the growth of bacteria, though it does not necessarily kill them all. It may prevent their development without destroying their life. The term *germicide*, when properly used, refers to treatment which totally destroys all microörganisms. The agents which are used as antiseptics are also commonly capable of acting as germicides if they are used in larger quantities, and, on the other hand, germicidal substances may be only antiseptic if used in small quantities.

In considering the question of disinfection in the household there are always two important questions to be considered: (1) What disinfectants are capable of destroying the bacteria? (2) How can these agents be most practically applied? It is of course manifest that not all germicides can be used under all conditions. Violent poisons, like corrosive sublimate, might be used in some cases, while it would be out of the question to use them in others. The question, therefore, of the application of the disinfectants is of even more importance than a knowledge of these antiseptics themselves.

Disinfecting Agents — Physical

The physical agencies which destroy microörganisms have already been considered in previous chapters, and a summary only is here needed. They are briefly the following:

Heat. All active and growing forms of bacteria are destroyed by moderate heat. In liquids a temperature of 140°, maintained for half an hour, is usually capable of destroying them, and a higher temperature quickly kills them. Spores, however, are not killed by a temperature short of actual boiling, and some spores are killed only by prolonged boiling. Moist heat of steam is more efficacious than dry heat. Bacteria spores may withstand a dry heat of 280° for some hours, but they cannot withstand a moist heat of steam that is much above boiling.

A matter of practical importance is the recognition of the fact that most of our contagious diseases are caused by microörganisms that do not produce spores. Consequently lower temperatures than boiling are commonly sufficient for disinfection. The only common disease that is known to produce spores is lockjaw; for while there are some other disease germs which do produce spores, the ordinary diseases of the household which we look upon as contagious are not, so far as we know to-day, disseminated by means of spores. Hence the practical conclusion is that for all of the common household diseases a moist temperature of 150° or 160°, maintained for half an hour, is sufficient for disinfection; but it must always be borne in mind that this will not disinfect spore-producing material.

Sunlight. Bacteria cannot stand direct sunlight for more than a few hours without being killed, — the brighter the light the more efficacious its action. While sunlight is thus an acceptable germicide, its practical value is limited because it has little power of penetration. Thin materials, like sheets, which can be exposed to direct sunlight, will be disinfected in the course of a few hours, but heavier materials, like blankets, will be disinfected only on their surface. Anything on which the sunlight can shine directly may easily be disinfected by this means, but in dimly lighted rooms light is of little value as a disinfectant. Its use is therefore limited to such articles as can be removed from the rooms and exposed to the sun's rays.

Cold. Cold is almost useless as a disinfectant. It delays the growth of bacteria for a while, but does not destroy them. We have already seen that long-continued freezing in ice will, after some months, destroy typhoid bacilli, but, except in the case of a few diseases, like yellow fever, freezing is of no value as a disinfecting agent.

DISINFECTING AGENTS — CHEMICAL

The most common methods of disinfection employ certain chemical agents known to have the power of destroying bacteria. There is a long list of germicidal substances. We need notice only those few agents that are in common use.

Corrosive Sublimate. This is one of the most efficient germicides, and its small cost has given it wide use. The most common strength for using it in ordinary conditions is one part of sublimate to one thousand parts of water. At this strength it rapidly kills bacteria. This strength may be used for washing floors or walls of infected rooms. It may be used for washing the hands after touching infectious materials. It is an excellent antiseptic, but there are two objections to it. (1) It is intensely poisonous, and the greatest care must be exercised in handling it, to prevent it from reaching the mouth. (2) It has a strong corrosive action on metals and cannot be used on anything made of iron or steel. These facts limit its use, but nevertheless it is one of the best and most widely used of chemical disinfectants. A solution of proper strength, one to one thousand, may be made by dissolving one quarter of an ounce of corrosive sublimate in two gallons of water. A more effective solution is as follows.

Corrosive sublimate	15 grains (1 gram)
Common salt	30 grains (2 grams)
Water	1 quart (1000 grams)

Carbolic Acid. This material has been used longer than any other disinfectant, and is very efficient, though less so than corrosive sublimate. It is commonly used in a proportion of about one part acid to twenty parts water, although sometimes it may be weaker and sometimes stronger. A solution of one part to twenty may be used for washing the hands, but stronger solutions will produce a burning of the skin. It may be employed for almost any of the purposes for which corrosive sublimate is used, but its value is less and its cost is considerably greater. One of the reasons for its popularity is the fact that it possesses a distinct odor, and people who do not properly understand the matter of disinfection have an impression that a disinfectant ought to have a strong odor. It should be understood thoroughly at the outset that *deodorants* are not *disinfectants*. Substances with strong smells do not ordinarily have any value as disinfectants. The *odor* of carbolic acid is totally without value, and the security which people feel when a disinfected room is filled with carbolic acid fumes is wholly misplaced. To disinfect the air requires materials of a different nature, and carbolic acid is not more useful as a disinfectant than are many other antiseptics that emit no odor at all. Corrosive sublimate, for example, is very much more efficacious than carbolic acid, although it is totally without odor. It may frequently be desirable in a sick room to have a deodorant as well as a disinfectant; but this is for comfort rather than for safety, and other deodorants can be employed which are equally as efficacious as carbolic acid. The burning of coffee grains in a room will usually destroy offensive smells and serve as a deodorant, although it is valueless as a disinfectant.

Chloride of Lime. This is one of the cheapest and at the same time one of the best disinfectants. It may be applied dry if the material which is to be disinfected contains moisture, but it acts only in the presence of moisture and should usually be dissolved in water. A solution of one part to twenty-five of water (one pound to six gallons) will be found to be very efficient in disinfecting walls, floors, furniture, etc. Chloride of lime is also one of the most efficient disinfectants for water. When added in very minute quantities, only one part of chlorine to a million of water, it kills the disease germs and is perfectly harmless in the water. It is very widely used to-day for this purpose and its use is extending rapidly. Common *slacked lime*, which is occasionally used, is of little value as a disinfectant.

Formalin. This material, as purchased, looks like water, and consists of a poisonous gas dissolved in water. The liquid itself is a very effective germicide, one part of formalin to ten thousand parts of water being sufficient to destroy the vitality of bacteria. Formalin has no more injurious action upon clothing than common water would have. Hence it may be used very freely in disinfecting any material that can be soaked in water. Its general use for washing is hardly practicable, because it gives off a gas that is very injurious to the eyes. It is also quite irritating to the skin, and must be carefully handled. For these reasons it is less widely used in the home than certain other disinfectants.

Creosote Disinfectants. A class of products derived from coal tar and going under the general name of creosote preparations are sold under a great variety of trade designations. They are all much alike in appearance and properties,— brown, oily-looking liquids, having a strong, tarry odor and forming a milky solution when diluted in water. They are very powerful disinfectants even when many times diluted, and are harmless to the skin unless applied too strong. They are, therefore, much better than any of the germicides just listed for disinfecting hands or for application to scratches and cuts in the skin. Their only disadvantages are that they have a strong odor and that they stain clothing which is disinfected in them.

Other Skin Disinfectants. Iodine has been used for years to disinfect small skin wounds, and is still favored by many physicians. It is so irritating, however, that a search has been made for something to take its place. Two proprietary disinfectants which are designed for just such usage are now on the market. Both are dyes, one yellow (acriflavine), the other red (mercurochrome). Neither is quite as effective as iodine; but for the treatment of minor skin injuries they are undoubtedly satisfactory, and are much more popular than iodine, as their use is not painful. Like iodine they stain the skin, a fact which is often of advantage to the physician, as it shows just what area has been covered with the disinfectant. A disinfectant of this type, therefore, is often used before vaccination or before making a hypodermic injection.

Application of Disinfectants

In determining the application of disinfectants two questions arise: (1) Where should the disinfectant be applied? (2) What is the proper disinfectant to apply? In most problems that confront the household there is little difficulty in determining the place where the disinfectant should be applied. We should look in at least four different directions: (1) *the excreta* and all discharges from the patient; (2) *the person* of the patient or of the attendant; (3) *clothing*, including all bedding, wearing apparel, etc.; (4) *the sick room* itself while occupied and after it is vacated.

Excreta. All discharges from a patient suffering from any infectious disease should be disinfected at once, since they will always contain infectious microörganisms. This would apply to the fæces, and all discharges from the mouth, as well as from sores on the skin, etc. Such discharges should be placed in a solution of corrosive sublimate, one part sublimate to five hundred parts water, or of chloride of lime, six ounces to a gallon. The quantity of the disinfectant should be large, and the material should be allowed to soak in it for at least an hour before it is thrown into closet or sewer. Such treatment effectually destroys its pathogenic nature. It is of course difficult to disinfect discharges from the skin, but all pus that exudes from such sores should be collected and thoroughly disinfected.

The Person. The disinfection of the patient during disease is rarely possible, and all that need be here stated is that the skin should be kept clean by bathing in water to which has been added a little glycerine. The disinfection of the person of nurse or attendant, however, should be most carefully attended to in cases of serious infectious diseases. The hands in particular are liable to become infected with the pathogenic germs, because they are used in handling the patient and his bedding. They should be frequently washed in soap and water, special attention being given to brushing the finger nails and removing all possible dirt from them. Afterwards it is well to put the hands for a moment in strong alcohol, and then, before drying, in a corrosive-sublimate solution, one part sublimate to one thousand parts water. After this the hands should be washed again in clean water. Other parts of the body should also be washed, although no part needs it so much as the hands. The hair should occasionally be washed in the same way, although, as already stated, the nurse should use a cap to protect the hair from infection as far as possible. These disinfections should be frequent in cases of serious contagious diseases, and should always be attended to when the nurse leaves the sick room to mingle with the rest of the family.

Clothing, Bedding, etc. These articles almost always offer difficult problems. The following general directions are all that can be given.

1. *Burn* everything which is not of very great value. This is the most thorough method of disinfection, and therefore care should be taken to use old, worthless articles as much as possible, in order that they may subsequently be burned without too great loss.

2. All of the articles that can be boiled should be subjected to a vigorous *boiling* for at least half an hour. This is sufficient for complete disinfection. It will apply to all forms of thin clothing, like cotton, and may be used for sheets, pillow cases, etc.

3. Articles too heavy for boiling, or those that would be ruined by boiling, cannot be so easily treated. Anything that can be soaked in water without injury can be disinfected by *soaking* it for three or four hours in a solution containing one part of formalin to five thousand parts of water. This is extremely cheap as well as easy to make,

and may be employed for soaking blankets and other articles not injured by water. The blankets should be placed in a tub, the tub filled with water, and formalin added in the proportion mentioned above, or even as strong as one quarter of a pint of formalin to ten gallons of water. A soaking in such a solution will be a thorough disinfection. For heavier articles like mattresses and comfortables, which cannot be soaked, complete sterilization is difficult. If there are at hand facilities for *steaming*, these articles may be disinfected in that way; but this is never possible at home, and can only be done by health boards. Mattresses in particular are difficult to disinfect and cannot be rendered perfectly safe. They may, however, be protected considerably by covering them with a rubber blanket, which will prevent their becoming contaminated. Whenever possible, one should use an old mattress of little value on the bed of a contagious patient, so that it can subsequently be destroyed. At present, however, health authorities recommend sunning and airing for disinfecting mattresses, rugs, and heavy bedding. Exposure to the sun and air for four successive days seems to be as efficient as more expensive methods of sterilizing. Disease bacteria ordinarily die when dried, and are quickly killed by sunlight.

Treatment of the Sick Room

While occupied. A room in which there is a case of contagious disease is, under the very best circumstances, a source of danger to all persons within the house, and it must be most carefully guarded to protect the other members of the family from danger. The treatment of the room during its occupancy and after its vacation must be totally different. While the room is occupied by the patient not very much can be done to control the contagion. Plenty of fresh air should be insisted upon, and obtained by the proper opening of windows, care being taken, of course, to shield the patient from draughts. If the room is occupied for some time, it may be well to wash occasionally all surfaces of furniture, floors, window sills, etc. with corrosive-sublimate solution as described above. The patient himself, in case of skin disease, may be bathed and his skin be kept moist with water containing a little glycerine or with vaseline. This will materially diminish the chance of having infectious material float from his skin around the room. All contaminated cloths should be burned immediately, and care should be taken that no one passes from the sick room to mingle with the other members of the family until he has changed his clothes.

Care after Vacating. After a room is vacated by the patient it must be disinfected before using it again. Concerning the proper treatment of such a room there have been many differences of opinion. For a considerable time it has been a common custom to treat such rooms by a gaseous disinfectant, the general practice being to close the room, sealing all cracks around windows and doors, and then to liberate the disinfectant. For this purpose formaldehyde gas has been most commonly used, although the fumes of burning sulphur have also been employed. Where such a method is employed it is always best to have it done by a health officer.

The use of gaseous disinfectants for this purpose is, however, going out of practice and has been largely abandoned by modern health officials. It has been found both useless and inefficient, and it is believed to give to the inmates of the house a feeling of false security. It is *the convalescing patient that is the source of danger to the rest of the household, not the room he has vacated*, and to allow him to leave the room and mingle with the family, giving them a feeling of security by disinfecting his room, is the height of unwisdom. Then, too, experiment has shown that these gaseous disinfectants cannot be relied upon as actually disinfecting the room. To treat a room by this method is very easy and therefore widely adopted, but it is not regarded to-day as of much value and is being abandoned.

The best method of preparing a room for reoccupancy is as follows: Carpets, bedding, curtains, and all cloth material should be removed and disinfected as above mentioned. Then all surfaces of the room, including walls, ceilings, floor, tables, chairs, and especially cracks around mopboards and floor, should be washed freely with chloride-of-lime solution, about one pound to six gallons of water. The room should then be aired by having the windows open for a day, after which it is ready for occupancy. Such a room is safer than one which has been "fumigated" by any gaseous disinfectant. It is well to remember that while most disease germs die quickly upon being dried, the tuberculosis bacillus may remain alive in a room for weeks or even months, and for this reason more care should be exercised in the room occupied by a consumptive than in the case of any other disease.

APPENDIX

DIRECTIONS FOR LABORATORY EXPERIMENTS

Apparatus. The experiments here described are all of a simple character. Many of them can be performed without any special apparatus; but some would need, in addition to test tubes, flasks, and other simple glassware found in any laboratory, a few pieces, as follows.

1. A steam sterilizer. An ordinary steamer such as used in the kitchen will do. A better form is shown in Fig. 81.

2. A hot-air sterilizer. The best form is shown in Fig. 82. Some sort of sheet-iron box which will serve the purpose may be found in almost all chemical laboratories.

3. Petri dishes. These are double glass dishes, Fig. 83, several dozen of which should be at hand.

4. Glass pipettes to hold 1 cc.

5. A few fermentation tubes, shown in Fig. 38.

6. Pieces of platinum wire fused into glass rods are convenient for transferring bacteria.

7. To carry out the microscopic studies there will be needed a microscope with a two-thirds and a one-sixth inch objective. A higher power is desirable though not necessary. In addition, glass slides and cover glasses will be needed.

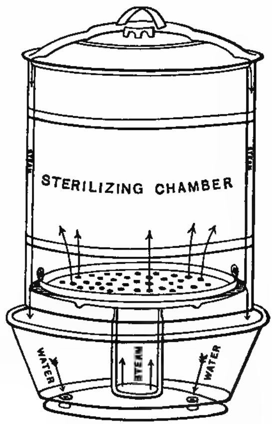


FIG. 81. Steam sterilizing apparatus.

The apparatus above listed (except the microscope) costs little, and many of the experiments can be performed with even simpler improvised material.

Method of Experimenting. The order in which the experiments are given is the one which most naturally follows the subjects treated in the body of the text, and should be followed as closely as possible. Where possible each scholar should perform the experiments, but this will be found impracticable in most cases. In such cases the experiment must be performed by the teacher in the presence of the class.

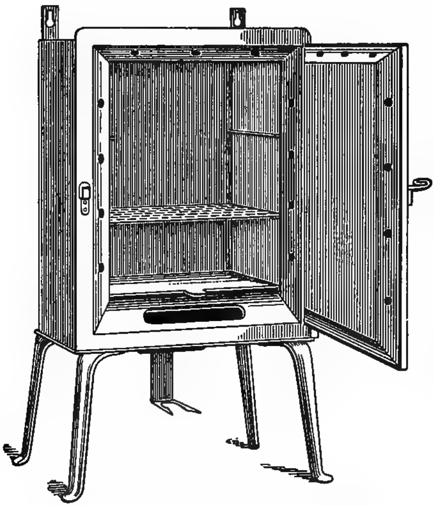


FIG. 82. Hot-air sterilizing apparatus.

Most experiments with microörganisms require two or three days for the bacteria to grow, and the observations must therefore be made some time after the preparation is made. Hence it is especially important that everything should be carefully and intelligibly labeled and that the scholars understand the meaning of the labels. When the teacher performs the experiments the scholars should see the preparation as well as the final results, and each scholar should make careful notes.

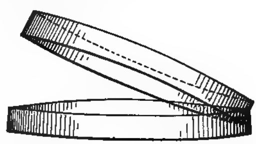


FIG. 83. A petri dish for plate cultures.

Sterilizing. All glassware must be sterilized before it is used. This is absolutely necessary and the success of the experiments will depend upon it. The glassware should be first washed clean. Then all test tubes, flasks, and fermentation tubes should be tightly plugged with cotton, as shown in Figs. 38 and 64, and then placed, with all other glass apparatus, in the dry sterilizer. By means of a Bunsen flame the sterilizer should then be heated to a temperature of about

340° (170° C.) and kept at this temperature for one hour. After cooling they are ready for use. In the following experiments it will be understood that all glassware should be sterilized before using.

Experiments illustrating the Molds

1. **Mold on Bread.** Place several slices of bread under a bell glass or any dish that will protect it from evaporation. Battery jars, large beakers, or even common bowls will answer. Moisten the bread with water and put aside in a warm place (80° to 95°). After two or three days the bread will usually show signs of white mold. Allow the mold to grow until some color appears and then determine, if possible, whether there are more than one species of mold on the bread.

2. **Molds on Different Foods.** Under separate bell glasses place bits of cheese, some pieces of lemon, and a bit of banana. Each of these should be moist. Cover and set aside as in the last experiment. Molds will grow in a few days, but probably different species will grow upon the different materials. Compare the molds and determine how many kinds can be seen.

3. **Experiment to show the Mycelium.** Place a little fruit juice, such as may be obtained from canned fruit, in test tubes or in homeopathic vials, and drop a few mold spores from the last experiment, or a little dust from the floor, upon the surface of the liquid. Set aside to grow, and notice how the molds spread and send fine threads into the liquid. Later notice that colored masses of spores grow in the air upon the surface but not in the liquid below.

4. **Spores.** After the molds of the previous experiments have begun to produce spores, as shown by the appearance of some color, remove a little spore material from the surface with a knife blade or a platinum wire and examine under a microscope. For this purpose a compound microscope is necessary, since the spores are very small.

5. **Growth of Mold from Spores.** Moisten a bit of bread and transfer with a platinum wire a little bit of the spore mass from a vigorously growing mold to the surface of the bread. Cover with a bell glass and set aside for growth. Examine every day, and note that molds start from the points where the bread was inoculated with the mold spores.

Preparation of Agar Culture Medium

For the following experiments it is necessary to prepare a jelly upon which molds will grow. A satisfactory jelly for this purpose is as follows:

To 15 grams of agar add 985 cc. of water and about 5 grams of Liebig's Extract of Beef and boil for half an hour. While still hot filter the material through absorbent cotton. In using absorbent cotton for this purpose a large funnel should be used and the absorbent cotton placed in it. The liquid agar is poured into the cotton, and it will run through readily, coming out as a tolerably clear solution. Some of the filtered jelly is to be placed in sterilized flasks and some in test tubes, about 10 cc. in each. Plug the flasks and test tubes with cotton, and steam the jelly in a common steamer for about twenty-five minutes. The jelly is to be cooled and put aside for twenty-four hours. At the end of that time it should again be placed in the steamer and steamed for half an hour. Once more set it aside for twenty-four hours, and upon the third day steam it again for half an hour and cool. Material thus prepared should give a slightly brownish jelly, which, if properly sterilized, will keep indefinitely. It should be *acid* to litmus paper.

If the teacher does not care to go to the trouble of making the agar, she can buy it of dealers in bacteriological supplies. The agar culture medium which is sold by such dealers is slightly alkaline, and should be rendered a little acid by adding HCl until the mixture will just turn blue litmus paper red. Molds require an acid medium, though bacteria need one with an alkaline reaction.

6. **Mold Spores in Dust.** Melt the agar in three or four of the test tubes prepared as above described, and pour it from each into a sterilized petri dish. Replace the cover upon the dish and allow the agar to harden. Sweep a little dust from the floor and scatter over the surface of the agar in one petri dish. Scrape some dust from a crack in the floor and sow on another dish. In the same way sow dust from other places upon the agar. Set aside until the molds begin to grow, and examine the mold colonies.

7. **Molds in a Dust Cloth.** Prepare two petri dishes of hardened agar, as in Experiment 6, and, after removing the cover, shake the dust

from a dry dust cloth over one of them. After leaving it thus exposed to the air for two minutes, replace the cover. Over a second dish shake a damp dust cloth. Set both aside and compare the number of molds that grow in the two plates. Has the dampness prevented the distribution of mold spores?

8. **Molds in the Air** (*a*). Prepare four dishes of hardened agar. Expose two of them to the air of an ordinary room that has been quiet for some hours — for example, a schoolroom before the school has assembled — by leaving the cover off for two minutes and then replacing it. Expose two other plates for the same length of time at the close of the school session after the air has become stirred up. Another pair of plates may be advantageously exposed in the hall while the scholars are passing. All plates should be exposed for the same length of time, carefully labeled, and set aside at the ordinary room temperature for growth. Count the number of molds that grow in each plate. A few bacteria colonies will be likely to appear on some of the plates, but these can easily be distinguished from molds, since they do not have the fuzzy appearance due to the mold mycelium.

9. **Molds in the Air** (*b*). Repeat the above experiment, using moist bread instead of the petri dishes of agar. After exposure, place under bell glasses and set aside for growth. The results will be essentially the same as in the last experiment, though less striking.

10. **Growth from Spores.** Prepare a petri dish of hardened agar. With a platinum wire or the tip of a knife blade remove a bit of the spore mass from some mold obtained in a previous experiment, and transfer it to the surface of the agar. Touch the agar in this way in several places and then cover and set aside for growth. After two or three days note that a mold colony begins to grow from each spot where the wire touched, indicating that spores have been transferred to the jelly. Allow the molds to grow for two or three days, examining them each day with a microscope or, if a microscope is not at hand, with a hand lens. Note the extension of the mycelium through the agar, and later the development of minute tufts of spores on the surface.

11. **Germination of Spores.** Sow mold spores upon the surface of a petri dish of hardened agar as follows: Select one of the

dishes previously inoculated and showing mold colonies in vigorous growth, some of which bear spores. Remove the cover, invert it over a second dish of hardened agar, and gently tap the dish containing the molds. This will cause the spores to fall in a shower into the second dish. Replace the cover and set the newly inoculated dish aside for growth. After one day examine the surface with a microscope to see if the spores have begun to germinate. Usually they will not show much growth before two days. When they begin to germinate study carefully with a microscope. This may be best done by dropping a thin cover glass upon the surface of the agar and then studying the spores with a high-power objective ($\frac{1}{6}$-inch). The germinating spores will show threads protruding from them, as shown in Fig. 4, p. 15. Examine daily for several days. After about three days it will be possible to see the fruiting branches beginning to grow from the ordinary threads, as shown in Fig. 5, p. 15. This study is very instructive, but cannot of course be made without a good microscope.

12. **Fruiting of Molds.** In the same way study a variety of molds. To obtain a variety is usually easy. One needs only to expose to the ordinary air two or three of the petri dishes and several species of mold spores are almost sure to drop in. They cannot be distinguished until they begin to develop their fruit, when they can readily be separated by a low-power microscope or a hand lens. If the spores are sown on agar, as above described, the method of development of the fruit may be studied. Methods of producing fruit in the common molds are shown in Figs. 10–17. The study of two or three species is sufficient, although the larger the number of studies the better.

13. **The Effect of Drying.** Place under a bell glass two slices of bread, one of which is damp, either naturally or by being slightly moistened with water, and the other dried. Leave for two or three days and notice the effect of drying in preventing the growth of molds. If one slice remains dry, no molds will grow upon it though the other soon becomes covered.

14. **The Effect of Boiling Temperature.** In each of two test tubes of agar place a small quantity of mold spores. Melt the agar in the tubes at as low a heat as will melt it. Pour the contents of one tube into a petri dish and cover at once. Place the other tube in

a beaker of boiling water and allow the water to boil briskly for half an hour, after which the agar is to be poured into a petri dish and treated like that in the first tube. Set both dishes aside for mold growth, and examine at intervals for several days, noticing whether molds develop in both dishes or only in the first. If they grow in both, note the relative abundance in the two dishes.

15. **Effect of Low Temperatures.** Prepare two plates of hardened agar and sow mold spores upon the surface of each. Leave one in the ordinary room temperature and place the other in an ice chest or some other place where the temperature is low. Compare day by day, and determine the effect of low temperatures in checking or stopping mold growth. Do *any* molds grow upon the dish placed in the ice chest?

16. **Effect of Air Currents.** Moisten a slice of bread and sow mold spores upon it, or allow it to mold spontaneously under a bell glass. After it shows a luxuriant growth of mold remove the bell glass and leave it exposed to the currents of the air. Notice how the growth of the mold ceases and the delicate mycelium flattens down close to the bread.

17. **Molds in Cheese.** Obtain a bit of Roquefort cheese. Cut it open and remove a bit of the green mass in the middle by means of a knife point or a platinum wire. Sow this substance upon the surface of a dish of hardened agar and set aside for growth. After two or three days the molds will begin to develop and may be studied with a microscope. When they begin to produce fruit they should, if possible, be studied sufficiently to determine the species. This species of mold is figured in Chapter II and should be easily identified.

18. **Decay of Fruit (*a*).** Place in a jar a number of apples that have been bruised or cut, packing them in rather tightly. Scatter in the jar some spores of the common blue mold which will usually be found on some of the petri dishes already prepared. Close the jar and set aside. Prepare a second jar with some whole clean apples and treat in the same way. Compare the two jars for a week or two to see if decay makes its appearance in either or in both of the jars. Does bruising hasten the decay of the fruit?

19. **Decay of Fruit (*b*).** Make a cut through the skin of an apple with a knife blade that has been previously dipped into the midst of

a mass of mold spores, preferably the common blue mold. Put the apple aside in a jar and examine carefully until it decays. Note that the decay begins rather quickly and starts at the point of the cut where the spores were inoculated.

20. **Molds in Decaying Fruit.** Obtain some thoroughly decayed fruit, several different kinds if possible. Remove a bit of the decayed material with a knife blade and plant it in agar in a petri dish. Replace the cover and set aside until the molds begin to germinate. Allow them to grow for a number of days and then study with a microscope, determining if possible the method of forming spores and comparing them with the figures of molds given in the previous pages. Is the species found similar to any described in this work?

Experiments illustrating Yeasts

21. **Fermentation of Molasses.** Into a common test tube or any glass vial place a solution made by mixing one spoonful of molasses with ten spoonfuls of water. Rub up a little compressed yeast in water and put a few drops into the tube of molasses water. Set aside in a warm place and let it stand for about twenty-four hours. At the end of this time a vigorous fermentation will be seen. The liquid will have become somewhat cloudy, numerous bubbles can be seen rising through it, a froth forms on top, and a mass of sediment soon collects at the bottom. The bubbles are the carbon dioxide which is escaping into the air, the sediment at the bottom is the growing mass of yeast, and the alcohol, which looks just like water, is dissolved in the liquid and is of course invisible.

22. **Proof of the Nature of the Gas.** Prepare two tubes, as shown in Fig. 31. In tube *a* place molasses and water inoculated with several drops of yeast, as in the last experiment. Put the cork in place and insert the other end of the tube into a second tube underneath the surface of some clear limewater, as shown in Fig. 31. Set aside in a warm place until vigorous fermentation occurs. Note the bubbles of gas that arise from the fermenting tube and bubble up through the limewater. The limewater soon becomes turbid, showing that the gas contains carbon dioxide (CO_2).

23. CO_2 produced chemically. In test tube *a* of a pair of tubes similar to those used in the last experiment place a little cream of tartar in water; in another test tube dissolve some saleratus in water. Pour the saleratus solution into test tube *a*, close at once with a cork, and allow the gas produced to pass into limewater as before.

Microscopic Study of Yeasts

24. Resting Stage. Rub a bit of yeast cake in a little water so as to make a slightly cloudy solution. Place a drop of the solution upon a microscope slide, cover with a cover glass, and examine first with a $\frac{2}{3}$-inch objective. Note that the water seems to be filled with very minute dots. Study with a higher power ($\frac{1}{6}$-inch objective). Examine the yeast *cells*, noting the *shape*, comparative *size*, and the *vacuoles* inside of the cells, as shown in Fig. 32. Are the cells attached or are they mostly separate? Hunt for small buds upon the sides of the larger cells. Proceed in the same way with a little dried yeast cake and compare the yeast cells in size and appearance with those of compressed yeast.

25. Growing Yeast. With a pipette remove a drop of the sediment from growing yeast prepared as in Experiment 21. Place the drop on a slide, cover with a cover glass, and study as in the previous case. Remove some of the yeast found floating on the surface, and study in the same way. Note that the yeast cells are in groups. Make a sketch of several groups, showing buds of various sizes. Can you see the vacuoles in the cells, as in the first specimen? Note any other differences you can see between this growing yeast and the compressed yeast cake.

26. Staining Yeast. Place a drop of yeast upon a slide and cover with a cover glass. Place a drop of stain upon the slide beside the specimen. (Almost any stain will do. Eosin dissolved in water is satisfactory.) With a bit of blotting paper applied to the edge of the cover glass opposite to the stain, draw the water out so as to suck the stain under the glass. Allow the stain to remain about two minutes, and then place a drop of clear water beside the cover glass and with a blotter draw this under until it washes out the stain. Then examine the specimen and determine whether the yeast cells are stained red. It should be found that most of them are unstained, although a few are stained deep red.

27. **Staining Boiled Yeast.** Put some yeast in a test tube with some water. Heat to boiling for a few seconds and then remove some of the yeast with a pipette and stain it as above described. After washing, study to see if the yeast which has been killed by boiling stains better than the living yeast.

28. **Effect of Boiling.** Prepare two test tubes of molasses and water and inoculate both with a drop of yeast. Plug with cotton. Place one test tube in water and boil for ten minutes, and then leave both test tubes side by side in a warm place for two days, and determine whether the boiling has been sufficient to kill the yeast.

29. **Wild Yeast.** Prepare several test tubes of molasses and water as described and, without plugging with cotton, leave exposed in various places for two or three days. Determine by the appearance of bubbles whether fermentation occurs. If any change takes place in the liquids, examine with a microscope to determine whether yeasts have found entrance from the air or whether some other microörganisms are growing in the solution. Commonly *bacteria* will be found more abundantly than yeasts.

30. **Fermentation of Cider.** Grind up a few apples and strain the juice from the same by squeezing through cheese cloth. Collect the juice in test tubes and allow it to stand for a few days. A fermentation soon appears and the juice turns into cider. Examine the sediment with a microscope and detect the presence of yeast. Close up the tube with a cotton plug and leave it for a number of weeks, determining whether it subsequently becomes acid by the development of acetic acid.

31. **Fermentation of Grape Juice.** Proceed as above, using grapes instead of apples. The juice will become wine if fermentation occurs properly.

32. **Effect of Temperature.** Fill three test tubes with molasses and water as above described and inoculate each with three drops of yeast in water. Place one tube in a refrigerator, a second in a moderately warm temperature, about 70°, and a third in a warmer place, near a stove or radiator (temperature about 90°). Compare the three at the end of three, six, and twenty-four hours, and note the effect of temperature upon growth.

33. **Effect of Light.** Prepare two tubes in the same way and set one in a bright light and the other in a dark place. This may be best done by wrapping the tube in velvet or heavy black paper to keep out the light. Keep both tubes at the same temperature and determine whether light has any effect upon the rapidity of growth.

34. **Effect of Age on Yeast.** Obtain an old sample of dried yeast cake. Prepare two tubes of molasses and water and inoculate one with a small quantity of the old yeast cake and two others with a similar quantity of a fresh cake. Set aside in a warm place and determine in which the fermentation starts sooner, and in which it is the more vigorous. Examine with a microscope after fermentation begins, to see if either contains other organisms besides yeast.

35. **Comparative Fermenting Power.** Make a dilute mixture of flour and water. Fill three fermentation tubes with the mixture, as shown in Fig. 38. Inoculate one with compressed yeast, a second with dried yeast cake, and a third with brewer's yeast, if it can be obtained. Set all three aside in a warm place for one day, and determine the relative fermenting power of the different yeasts by comparing the quantities of gas that collect in the closed tubes.

36. **Action of Yeast on Bread.** Mix up a little flour and water to about the consistency of dough for bread making, and divide into three lots. Into *a* and *b* place a little compressed yeast. This may best be done by dissolving the yeast in water and stirring it into the dough during the mixing. *a* and *b* are then to be placed in a warm place for five or six hours, while *c*, without the yeast, is to be baked at once. After *a* and *b* have risen under the influence of the yeast, bake *b* at once in the oven, while *c* is to be thoroughly kneaded and then baked. Compare the results of *a*, *b*, and *c*, noticing the difference in the textures of the bread.

37. **Overraising.** Mix another lot of dough with yeast in the same way and allow it to rise in a warm place for twelve hours or more. Test with litmus paper to see if it is acid. Bake and taste to see if it has become sour.

38. **Bread raised by Wild Yeast.** Put a small amount of salt in a little milk and then allow it to stand in a warm place until a froth appears. Mix it with flour to make a dough and set aside to rise.

Does the dough rise as rapidly and as satisfactorily as when yeast is used? Does the baked dough have the same taste?

39. **Kumiss.** Into a quart of milk put two tablespoonfuls of common sugar and add about one sixteenth of a compressed yeast cake. Put in a warm place and leave for twenty-four hours. Cool and taste. It will be kumiss, or fermented milk. Is it sour?

Experiments illustrating Bacteria

40. **Putrefaction.** Place in a series of test tubes, with a little cold water, the following: (a) a bit of raw meat; (b) some white of egg; (c) some flour; (d) some crushed beans; (e) sugar; (f) starch; (g) a bit of melted butter. Set all of these tubes in a warm place for two or three days and determine which will putrefy and which will not.

41. **Effect of Moisture.** Place a little of the following foods in test tubes: (a) dry beans; (b) Indian meal; (c) a piece of dry bread; (d) graham meal; (e) flour; (f) common crackers. In another series of test tubes place the same materials moistened with water. Set all aside in a warm place and notice the effect of water in bringing about putrefaction.

42. **Effect of Temperature.** Place bits of meat with a little water in three test tubes. Put the first tube in an ice chest, the second in ordinary room temperature, and the third close to a stove or radiator, where the temperature is high. Notice the rapidity of putrefaction in each case.

43. **Effect of Boiling.** Chop finely some raw beef and place it in water, warming slightly but not heating it to more than 130°. Divide into two parts, place each in a test tube, setting one aside without further treatment, but bringing the other to a brisk boil for a moment and then setting beside the first. At the end of twenty-four hours examine to determine if putrefaction has occurred.

44. **Effect of Freezing.** The following experiment can be performed only in cold weather. Place a little hay in water and heat to a lukewarm temperature, leaving the same to steep for half an hour. Filter through filter paper into two test tubes. Plug with cotton and set one of the test tubes in a warm place. Put the other out of

doors where the liquid will freeze. Allow it to remain frozen for a few hours, and then bring it back into a warm room, leaving it there for a few days to see if it putrefies, in order to determine whether freezing destroys the life of the bacteria in the hay infusion. For this experiment it will be better to use a metal dish instead of a test tube, since freezing might break the test tube.

45. **Effect of Boiling upon Spores.** Put some hay into a dish and steep with warm water at about 120°. After an hour's steeping filter through filter paper into four test tubes, filling each half full, plugging the same with cotton, and labeling them *a*, *b*, *c*, *d*. Bring *a* to a boil for five minutes, *b* for ten minutes, *c* for twenty, and leave *d* without boiling. Set aside for a few days to determine whether the material in all cases putrefies. Does the hay infusion contain bacteria spores that are not killed by boiling?

46. **Action of Disinfectants.** Mix the white of an egg with ten times its bulk of water and place the material in a series of test tubes, filling each about one third full. To the tubes add the following disinfectants: (a) no addition; (b) one quarter of a gram of salt; (c) one gram of salt; (d) one gram of sugar; (e) five grams of sugar; (f) two drops of a corrosive-sublimate solution (one part sublimate to one thousand parts water); (g) six drops of corrosive-sublimate solution; (h) one drop of formalin; (i) two drops of formalin; (j) three drops of formalin; (k) one eighth of a gram of borax; (l) one fourth of a gram of borax; (m) four drops of carbolic-acid solution (one part acid to twenty parts water); (n) ten drops of carbolic-acid solution. Set all test tubes in a warm place side by side and examine daily, noticing the effect of the various ingredients in preventing decay, and noting how much more powerful some disinfectants (corrosive sublimate) are than others (carbolic acid). Numbers h, i, j, m, and n should be closed with a cork to prevent the disinfectant from evaporating.

47. **Vinegar.** Soak a bit of raw meat in vinegar, warming it somewhat and leaving it for several hours. Remove the bit of meat, placing it in a test tube plugged with cotton, and leave for a few days, to determine whether it putrefies or whether the vinegar acts as a disinfectant. The vinegar will prevent putrefaction if enough is used.

Microscopic Study of Bacteria

It is rarely feasible to carry on any extended microscopic study of bacteria with ordinary classes. The organisms are so minute that they require very high powers and expensive microscopes, and are so simple that the scholar can learn very little by their study. A brief examination of a few bacteria may, however, be useful. If desired it can be done as follows.

48. **Study of Living Bacteria.** Obtain a bit of decaying meat, decaying egg, or some other proteid material, and place a minute drop of it upon a slide in a drop of water; cover with a cover glass and study with the highest objective obtainable. A $\frac{1}{12}$-inch objective is required to study them, but a $\frac{1}{6}$-inch will usually be sufficient to show the bacteria as minute specks, many of which will commonly be seen swimming rapidly under the field of the microscope. If decaying material from different sources is studied, there will usually be found several kinds of bacteria, as indicated by the different sizes and shapes.

49. **Staining Bacteria.** To make a more careful study of these organisms, they must be *stained* in order that they may be more clearly visible. Staining fluids may be bought or a convenient one be prepared as follows:

Ziehl's Carbol-Fuchsin

Saturated alcoholic solution of fuchsin	5 cc.
Five per cent. solution of carbolic acid	45 cc.

To stain bacteria place a very small drop of some decaying mixture upon a cover glass in a drop of clear water. Spread it over the cover glass in as thin a layer as possible, and then allow it to dry in the air. After drying take the cover glass in a pair of forceps and pass it rapidly through a gas flame three times. This is to *fix* the bacteria upon the slide. Place a few drops of the staining fluid upon the bacteria on the cover glass and allow the stain to remain for five minutes. Then wash thoroughly in a stream of running water and place the cover glass upon a slide in a drop of water, bacteria side down. Study with the highest-power objective. The bacteria will be found to be stained brilliant red. It is instructive to examine a number of decaying fluids in this way.

50. **Bacteria from the Teeth.** Scrape a little tartar from the teeth, spread upon a cover glass, and stain in a similar manner.

Further microscopic study of bacteria requires higher-power objectives and more apparatus than can be found in ordinary schools.

Culture Experiments with Bacteria

Nearly all experiments in bacteriology involve the use of culture media prepared for the purpose. Such culture media may be made by any one who has at his command a laboratory with proper apparatus for sterilizing. If a teacher does not have facilities for making culture media, they may be bought from the dealers in bacteriological apparatus. The following is easy to prepare.

Gelatin Culture Medium

Mix together in a common stew pan the following:

1 liter of water.
5 grams of Liebig's extract of beef.
10 grams of peptone.
100 grams of gelatin.

Carefully weigh the mixture in the dish in which it is to be boiled. Heat the mixture at about 140° until the gelatin is thoroughly melted, and then boil briskly for a few moments. Test with litmus paper. It will be found to be acid. Add to it, drop by drop, a solution of caustic soda ($NaOH$) until it is slightly alkaline to litmus paper. Boil briskly for half an hour. Weigh once more, add enough water to bring it up to the original weight, and test again with litmus paper. If the reaction is still slightly alkaline, the material is ready for filtering. Filter through absorbent cotton, as already described, and collect the clear liquid in a sterilized liter flask. Fill with the material as many sterilized test tubes as it is desired to use, putting about 10 cc. in each, which should fill them about two inches deep. Replace the plugs and then steam all of the gelatin in a steamer for about half an hour. Set aside for twenty-four hours, and steam again; and after another twenty-four hours steam a third time. If properly made, the material will still be clear, and, being now sterile, will remain clear indefinitely. It differs from the medium prepared for molds chiefly in being alkaline instead of acid.

Agar Culture Medium

For most purposes a modification of the above is desirable. It is made in the same way, except that, instead of using 100 grams of gelatin, there are placed in the mixture 1.5 grams of agar-agar (a preparation from a sea moss which may be purchased from dealers). This is known as *agar culture medium*. In other respects it is made precisely as above, except that more heat is required to melt agar than to melt gelatin.

51. **Bacteria in Tap Water.** Melt six of the agar tubes by moderate heat. By means of a sterilized pipette, preferably one that holds exactly one cubic centimeter, place in each of the six tubes a cubic centimeter of water drawn directly from the tap. Mix the water thoroughly with the agar and pour the contents of each tube into a petri dish, covering it at once and allowing it to cool. Set aside at a temperature not above 70°. In about two days the dishes will be found to be covered with little dots known as *colonies*. These will be somewhat variable in appearance, but since each colony represents what was a single bacterium in the original drop of water, the counting of these colonies in the plate will give the number of bacteria in the tap water.

52. **Bacteria in Well Water.** Proceed in the same way with the water drawn from a well if it is obtainable.

53. **Bacteria in Miscellaneous Waters.** Obtain samples of water in sterilized bottles from several sources — horse troughs, gutters, running water of the streets, snow, etc. — and treat them in the same way as described above. Comparison of the plates will give an idea of the relative number of bacteria in water from different sources.

54. **Bacteria in Ice.** Obtain a piece of ice and melt it in a sterilized beaker. Place a cubic centimeter of the water in gelatin and proceed as above described.

55. **Bacteria from Various Sources.** (*a*) Into three tubes of melted gelatin culture medium place a small drop of saliva. Mix thoroughly with the gelatin and pour into petri dishes. (*b*) Place in other tubes of melted gelatin, and also of melted agar, *very small* bits of decaying meat or decaying egg. Mix thoroughly in the gelatin by rubbing with a sterilized glass rod and pour out into a petri dish. (*c*) Into a third set of tubes place small pieces of dirt swept up from the floor or picked out of cracks in the floor. Mix with the gelatin and pour into petri dishes. (*d*) Into a fourth set of tubes place a little dirt from the street and proceed as before. Allow all plates to grow till the colonies are visible. Note any differences between them.

56. **Bacteria on the Fingers.** Pour agar into some petri dishes. After it has hardened touch its surface with the fingers, replace the cover, and set aside for bacterial growth. Wash the hands thoroughly in clean water, wiping with a clean towel, and then proceed in the same way with a second petri dish, touching the surface with the fingers and setting aside for growth.

57. **Bacteria in the Air.** Melt the contents of four tubes of gelatin and four of agar. Pour each into a petri dish, replace the cover, and allow the contents to harden without inoculation. Expose one gelatin and one agar plate to the air of a schoolroom before the school session, by removing the covers and leaving the plates uncovered for three minutes. Expose two similar plates at the close of the school session in the same way. Expose two in the hall at the time when many scholars are passing through it. Expose two in a room after sweeping or dusting. In all cases the plates are to be exposed the same length of time, carefully labeled, and set aside for the bacteria to grow. The relative number of bacteria is readily determined by an examination of the plates. Molds will grow upon the surface of the plates, but a little study will make it possible to distinguish them from bacteria. The bacteria will commonly be more numerous than the molds. Similar plates exposed in a variety of locations will be very instructive as indicating the abundance of bacteria in the air.

58. **Bacteria in Milk.** In an ordinary flask place one hundred cubic centimeters of water and sterilize by steaming for two hours. After cooling place one cubic centimeter of ordinary milk in the flask and mix thoroughly by shaking. Melt three tubes of gelatin and three

of agar. Into one tube of each place one cubic centimeter of the diluted milk; into a second tube of each place one half of a cubic centimeter, and into a third a single drop. Mix thoroughly, pour into petri dishes as usual, harden, and set aside for growth. If possible, count the number of bacteria on the plates and estimate the number per cubic centimeter (a single drop is about one fifteenth of a cubic centimeter). The number will sometimes be too large to make this possible.

59. **Effect of Temperature upon Milk.** Fill six test tubes full of milk. Place two of them in an ice chest, two at ordinary room temperature, and two close to a stove or radiator where the temperature is very warm. Examine at intervals of three or four hours and note the time at which the tubes become sour and curdle. Determine, if possible, whether there is any difference in the appearance or smell of the curdled milk in the three samples.

60. **Effect of boiling Milk.** Fill two test tubes one third full of milk. Place one of them in water and allow the water to boil briskly for five minutes. The second one is not to be boiled. At the close of the boiling plug both test tubes with cotton and set side by side in a warm place. Examine each day and notice the difference in the changes that take place in the milk. One sample will probably sour quickly; the other will keep very much longer and will not sour, even after many days, although it will spoil. Test both samples with litmus paper, after they have spoiled, to see if both are acid.

61. **Growth of Bacteria in Milk.** Obtain some absolutely fresh milk. This experiment may be difficult in a city where fresh milk is not easy to obtain. Place one cubic centimeter of the milk in one hundred cubic centimeters of boiled and cooled water, mix thoroughly, and then with a clean sterilized pipette place one cubic centimeter of the diluted milk in each of six test tubes of melted agar culture medium. Mix thoroughly, pour into petri dishes, and set aside for the bacteria to grow. Place the milk at a warm temperature near a radiator for six or eight hours, and repeat the experiment, making six more petri dishes in the same way. Set all aside, and after the bacteria have grown count the number of colonies in each, thus determining the rate of multiplication of bacteria between the first and last experiments.

62. Washing of Milk Vessels. Place some ordinary milk in two test tubes and set aside until the milk sours. Pour out the milk from all the test tubes and wash one with cold water and the other with hot water and soap. Hold the tubes up to the light and notice the difference in the cleanliness of the two test tubes. Now fill each tube with fresh milk and set aside in a moderately cool place and notice in which of the tubes the milk sours first.

63. Vinegar Bacteria. Obtain a little good vinegar containing some of the mother of vinegar. Put a bit of the mother upon a glass slide, cover with a cover glass to spread in a thin layer, and study with a high-power microscope.

64. Effect of Heat in sterilizing Fruit. Fill four test tubes about half full of water. In each place a few small berries, like blackberries or blueberries, or pieces of cherry, apple, or pear. Plug each tightly with cotton. Put one aside and label *a*. Place the others in cold water and gradually bring the water to a boil. Before the water boils take out one test tube and label it *b*; take out a second the moment the water boils and label *c*; remove a third after the water has boiled half an hour and label *d*. Set all tubes aside in a warm place and watch for several days, determining which are successfully sterilized, which will be indicated by their not spoiling.

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