
FERMENTATION
IN ITS HOUSEHOLD RELATIONS.

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We give the name *fermentation* to a peculiar kind of chemical change, in which the decomposition of a compound is caused by the presence of some other substance known as a *ferment*. The word is as old as our language, and the thing it represents has been known ever since Noah made wine, and perhaps longer, but its real nature has been understood for only a few years. Even now only its main features are proved with reasonable certainty. Lying just beyond what is proved there is a wide field belonging to this subject, in which the proof is not yet complete, where we have some considerable evidence, but not enough to establish the principle beyond question. Still outside of this lies another great class of facts which can best be accounted for on the principle of fermentation, where the analogies and inferences are so very strong in that direction that a plausible explanation may be given to otherwise very mysterious processes, but where, after all, we have as yet very little actual proof. Some of these are of so much interest to science, and at the same time of such vast importance to our race, that the whole matter is now receiving much attention and study in one way or another, and is probably the subject of more refined and zealous investigation, than any other department of natural science.

It is a hard subject to make clear in a popular lecture, but

I will use as few technical words and phrases as possible. I will first explain what kind of compounds can be fermented, next the nature of fermentation itself, and then I will give illustrations of the household applications, grouping these into four classes. But I must say in beginning that some parts of the subject which are of great practical interest I must pass by with a mere reference, and others leave out entirely. The subject is too large to be crowded into one lecture.

MINERAL COMPOUNDS.

Chemical compounds are usually grouped into two great classes, the *mineral* (or inorganic) and the *organic* classes. Mineral compounds are usually simpler in their composition and not so easily decomposed. Some of them, like common salt, alum, saltpeter, borax, water, carbonic acid, etc., are found in nature, and can also be made by art, the natural product in nowise differing from the artificial one. Many others, which are not found ready made in nature, can be made by art from the original elements. There are a vast number of mineral compounds, all the elements are found in them, they differ very greatly in their physical and chemical characters, but as a class they can be made by the chemist. He can make (or *compose*) them from their elements, and can unmake (*decompose*) them at his will and pleasure.

ORGANIC COMPOUNDS.

But the compounds of the other great class the chemist cannot make from their elements. He cannot *compose* them, he can only *decompose* them. They are made in nature by (or rather *in*) living plants and animals, or are the result of the decomposition of something that has once formed part of a living thing. They are called *organio* because they are produced in living organisms. Until lately chemists drew a sharp line between these two great classes of compounds; now, however, the line has been broken in a few places, and a few of the so-called organic compounds have been made artificially by chemists. For our present purpose it is more convenient to keep up the old and popular distinction, as the

number which have been made entirely by art is very small indeed compared with the vast number which have not, and these only as chemical curiosities, never yet as a commercial or useful product. Some classed by chemists among the organic compounds have been called "mineral" in popular language because derived from fossils, but this need not confuse us—they only grew long ago.

Organic compounds as originally formed are usually of more complex chemical composition than the mineral ones, and so soon as the plant or animal which produced them is dead they readily decompose into some simpler compound, and by further decomposition these in turn change into still simpler ones, until at last they are resolved into those mineral compounds which the original plant lived on in the soil, water, and air.

Organic compounds are essentially composed of four elements, carbon, hydrogen, oxygen, and nitrogen, sometimes with the addition of another, as sulphur or phosphorus. As a rule, those which contain much nitrogen decompose easier, and stink badly during their natural decay, or as we say, they *putrefy*.

FERMENTATION.

Fermentation, as has been stated, is a kind of decomposition which must be started by a *ferment*. There are two classes of ferments, known respectively as the *living* and the *soluble* ferments.

The living ferments are of so much more importance in this connection than the soluble ones that I will devote this lecture entirely to them, and will use first the most common illustration.

You are familiar with sugar. It is formed in the sap of many plants, such as sugar-cane, sorghum, maple, etc., it is in the juice of our common fruits, giving them their sweetness. There are several kinds of sugar; some are sweeter than others, some can be crystallized, others not, and they differ also in other properties. Some, like the sugar of milk, are formed in animals, but I will pass them by now. In the plants where it is formed it is always dissolved in the sap

along with other organic substances. If it be purified, as is done more or less perfectly in the manufacture of sugar, it will then keep pure for an unlimited time,—that is, it will not decompose of itself. It may be dissolved in water, and the solution, if kept pure, does not decompose, and may be kept indefinitely—for ever, as far as I know.

Suppose, however, that we add a little yeast to it. Or, better, as a more familiar illustration, add a little yeast to the sweet juice of apples or grapes, and keep it at the right temperature, not too cold nor too warm. Soon a disturbance begins, the liquid begins to *work*, as we say, and becomes more turbid, fine bubbles of gas are formed, there is a slight rise of temperature in it. If we let this go on until it runs its course, we find after a time that the disturbance ceases, no more gas is given off, the temperature falls to that of the surrounding air, the turbidness grows less, a sediment falls to the bottom, and in time the liquid again becomes entirely clear. We say that it has *worked* itself clear.

It is, however, no longer a solution of sugar; it has no sugar in it; it has lost all its sweetness and is sour—it is vinegar. If we had stopped its working when but half done, and at just the right time, we would have had neither sweet sugar nor sour vinegar, but alcohol. All this has been done by the action of the yeast.

YEAST.

When yeast is seen with the microscope it is found to consist of countless multitudes of *cells*. This fact could never be known until microscopes were invented, because they are too small to be seen by the naked eye, and the discovery was made in the very earliest days of microscopy, by the Dutch microscopist *Lewenhoeck*, in 1680. A century later, in 1787, an Italian, *Fabroni*, stated that yeast was a *living* organism, having both a vegetable and an animal nature. It is, however, within the last forty or fifty years that the true nature of yeast and similar ferments has been demonstrated, and much less time since all the more important facts now known have been demonstrated. I will not attempt any details of

the history of this interesting question ; I will merely say that all such ferments, of which yeast is the type, are *plants*, very low in the scale of being and very simple in their structure, yet living, growing plants, having their own laws of growth, of life, and death. By botanists they are classed with the *fungi*.

All living beings are made of cells, each cell too small to be seen by the naked eye. The living cell is a little closed sac, filled with a liquid. There are two or more coats or walls to a cell ; the outer is thicker and coarser, the inner thinner and more delicate,—the two coats adhering closely together, like the fine lining to a coarser bag. No hole can be found through the coats of a cell, but water passes in and out freely. It is porous, although no pore can be found with the most powerful microscope. All growth, whether in animals or plants, is by the division and growth of cells. Every plant and every animal (if it come from a spore or seed or egg) probably begins its life as a single cell ; it develops and grows by the cells dividing and multiplying, and during this growth various substances which are brought in contact with these living cells are changed in their composition by it. The process of growth depends upon this, and in some way all the organic compounds we find in either plants or animals are composed or made in this way. The changes go on in the substances that are dissolved in the juices of the plant, and thus are brought in contact with the walls of the living cells.

I have said that yeast is composed of vegetable cells. Now it is found that during such fermentation as I have described (as when cider works), these living yeast cells multiply and grow in the fermenting liquid, and they continue to grow and multiply as long as the change is going on. If we kill these living and growing yeast plants (for plants they are) we stop the fermentation. The chemical changes go on only when the cells are living and growing. You all know that if we *boil* yeast it is no longer good for anything. If we examine yeast with a microscope, just after boiling, we find that the cells are killed, they are shriveled, often collapsed ; sometimes the coats are partly separated from each other, and the material

has all the character of a dead substance rather than a living one. It easily decays, and smells badly during the process. Many poisons act in the same way; they *kill* the living cells, and when their life is gone they will no longer induce fermentation.

There was a long and bitter controversy among scientists regarding the nature of the chemical changes during fermentation, whether the living cells caused the chemical change, or the chemical change caused the cells. This, in the case of yeast, was settled beyond question less than a score of years ago; and, indeed, here and there an old man is still skeptical. Without entering into this controversy it is enough to say that no eminent scientific man now denies the fact that the living and growing cells are the *cause*, not the result of the chemical decomposition that takes place in ordinary fermentation; the debatable ground is now pushed further along, and the question now is, whether *any* organic compound found in the animal or plant would decay at common temperatures except by fermentation or a process analogous to it.

There are many species of living ferments, and each species produces its own kind of fermentation. One species, in the working of cider, or beer-wort, or whiskey-mash, produces alcohol, and consequently we call it the *alcoholic* ferment. Another, in souring milk, produces lactic acid, the principle of sour milk, and we call that the *lactic* ferment, and so on to a great number which have been studied by chemists and microscopists, and descriptions and pictures of them are to be found in the books relating to this subject.

Where living beings are complicated in their structure, and have many organs, many different chemical compounds are elaborated during their growth by their various cells. In a corn-plant, with its roots, and stalk, and leaves, and tassel, and silk, and ear, and in the different parts of each organ, in the whole plant there are many chemical substances produced, such as woody-fiber, and starch, and sugar, and oil, and albuminoids, etc. But where the plant is very simple in its organization, like one of these ferment-plants, the chemical work is correspondingly simpler, and but few compounds

are produced. There is this difference, however,—the higher organism, like the corn-plant, forms its products from the mineral and decaying matter it finds in the soil, air, and water. It is a process of building up from the simpler to the more complex. Not so the ferment-plant. It does not build up, it only tears down what has already been built up by the higher organisms. Moreover, it changes vastly more than it uses. A little yeast will change all the sugar in a whole barrel of sweet cider to vinegar. The higher organisms are builders, the ferments are destroyers.

Whenever we have a fermentable liquid exposed to the free air fermentation soon starts—*apparently* spontaneously,—that is, without our adding any yeast or ferment.

The explanation is that the ferment-organisms are *very* small and very abundant. Some of them (and possibly all) have two ways of propagation. The usual way is by cell-division,—that is, an old cell divides and makes two or more new ones, and these again divide, and so on. The other method is by fruiting. The fruit or seed of any fungus is called a *spore*; botanists do not call it a *seed* because its structure is very unlike that of a seed, but it plays the same part in nature, producing a new plant. Spores are always *very* minute, very much smaller than any seed. The adult cells of the yeast plant are but $\frac{1}{3200}$ to $\frac{1}{2800}$ of an inch in size, and the spores are correspondingly more minute. The cells of the lactic ferment (which sours milk) are only $\frac{1}{10000}$ of an inch; of the butyric ferment (which makes butter rancid), $\frac{1}{14550}$; and others, particularly the septic ferments, still smaller.

We have strong reasons for believing that some spores are entirely too small to be seen by the most powerful microscopes ever made, and yet capable of germinating when the conditions are right.

Of late years many careful observations have been made on the nature of the fine dust which floats in the air, and it is proved that many spores are floating about, and even the dried cells themselves, dry but not dead, ready to start fermentation if they fall where they can grow. Dust, with invisible ferments, or their spores, is everywhere in the open

air; the particles fall on the fruits, get into their juices when it is expressed, and start the fermentation, which once started then goes on of itself. It has been claimed that it constitutes in part the delicate "bloom" on grapes and certain other ripe fruits.

The various ferments differ in size, in shape, in organization, and produce different chemical results.

All plants require oxygen for their growth. The higher plants must have it free, from the air, but ferments may get it in other ways. Thus, when sugar is the fermenting substance, the yeast-plant needs some free air to start with, but then it will go on without air, it will even grow in an atmosphere of carbonic acid. The sugar itself contains oxygen, and during the fermentation the yeast-plant gets its oxygen from that. It may be that this is the actual cause of the decomposition.

But this is no place to discuss the theories as to the way the chemical change comes about. Suffice it to say that decomposition does go on during the growth of the ferment, and that fermentation in some form is the common way in which organic substances begin their decay in nature.

I have been thus lengthy in my introduction, because most of the household applications are only made certain in practice when we have a reasonably fair understanding of the principles involved. For example, canning fruit was never made a success in household practice until the true nature of fermentation had been demonstrated.

I said in beginning that I would notice four phases or classes of household applications. The first is of

FERMENTATIONS WHICH ARE WANTED.

We employ fermentation most in the raising of bread, in making fermented drinks, in making vinegar, and in a few cases in preparing foods.

The most common of these is the raising of bread before baking. Our starchy foods may be grouped into two great classes, the *bread*s and the *puddings*, or the light and the heavy. The light ones are raised in five ways, the first two by fermentation, the other three by other means.

The first is where *leaven* is the ferment. This is the oldest method, but in this country is rarely used in families, except as I will refer to again.

The second is where *yeast* in some form is the ferment. This is the usual way in families and in bakeries.

The third method is where some carbonate is used to furnish carbonic acid, bi-carbonate of soda now-a-days, bi-carbonate of potash (*saleratus*) formerly. Some acid or substance like cream of tartar is used to liberate the carbonic acid. It may be so mixed as to form a "baking powder," or it may be used with sour milk or some other acid.

The fourth method is by incorporating a gas under pressure. This requires much machinery, and produces the *crated bread*, so called. It is only done by bakers, and never in families.

The fifth method is where the mixing is done very cold, and where the liquids used are very cold, and consequently contain much gas or air dissolved, which is liberated by the heat of baking. It is claimed by some housewives that this is the method for the nicest of flakey pierust and for certain cakes in which milk is used.

But as no fermentation is involved in either of the last three methods, we will dismiss them and return to the first.

I have already spoken of fermentation which is *apparently* spontaneous, when fermentable substances are exposed for a time to the free air. If dough is mixed and allowed to stand, in a longer or shorter time it begins to ferment, and after an uncertain length of time sours without the use of yeast. This sour dough is *leaven*, which added to fresh dough starts that into fermentation; and this was the method used from the earliest time down to the last, and even extensively into the present century. It is less manageable than yeast, and has therefore fallen into disuse. Families sometimes resort to it still in back settlements where there is difficulty in getting yeast. Some years ago, when in the mountains and away from civilization, my cook in camp used this method with reasonable success, and I have seen it used by others in similar circumstances. I remember, when a very small lad, it was used in some families in a pioneer population, but now

the method has so completely passed away, in making bread, that many of the younger generation have never seen it. The principle, however, is extensively applied in the country for raising buckwheat cakes. The batter left over from the morning's baking is set by in a cool place until evening, when fresh flour is stirred in, the whole set in a place of the right warmth; the old batter is the leaven to the new, and in the morning all is light. This works well with care, going on for months, and *connoisseurs* of this delicious breakfast item claim that buckwheat cakes raised in this way are the best, are the most acceptable both to the palate and the eye.

The most common bread-ferment, however, is *yeast* in some form. In brewing, when the sweet infusion of malt (called *wort*) ferments, a frothy substance rises to the top, which is yeast. One way of "cleansing" beer is to fill casks with the fermenting wort, and let the frothy yeast work itself out the bung. Formerly this was done in tubs or vats, and the yeast ran out over the top. Hence the old English name of *emptyings*, a name still heard in rural districts (usually shortened to "*emptings*") for the ferment of bread. It is known to science as the *alcoholic ferment*. It is the same thing which produces the alcohol of cider and wine, and also of all our spirituous liquors. I have already described it as a fungous plant. It may be dried without losing its life; and dried yeast in some form is now a common article of sale, and is prepared in large quantities. In domestic practice, this same yeast-fungus dried along with Indian meal and an infusion of hops, prepared in a certain way, known under the old-fashioned name of "turnpike cakes," or simply "turnpikes," is extensively used in country homes, and many a successful housewife still thinks them superior to any of the more modern forms of yeast found in the stores.

For the highest success in raising bread, many precautions have to be taken to get the best results. As so many of the conditions are variable, particularly that of warmth, the successful baking of bread is more of an art than a science. I see by the smile this provokes among my lady hearers that they think so too, so I will drop this part, lest I be caught

tripping. I will only say that different flours act very differently in the rapidity and ease with which they go into fermentation. Some bakers are in the habit of mixing the different sorts so as to get the lightest bread, and the extensive use of potatoes in setting the dough has reference more to its relations to the fermentation than to anything else.

We must keep in mind that the real action of yeast is to change sugar into alcohol, and this in turn into vinegar. In raising dough and in making alcohol, the process must be stopped at the right time, and this is done by *heat*, which kills the ferment-fungus and stops its chemical work. If it goes too far the alcohol becomes vinegar, the bread or the beer sours. That alcohol is formed during the raising of the dough, and expelled by the baking, is proved beyond any doubt. Several patents have been granted for processes for saving this alcohol, and one company in London is said to have spent a hundred thousand dollars in trying to save this alcohol for commerce. It succeeded in saving alcohol in large quantities, but the ovens constructed so as to save it did not bake the bread so nicely. The people preferred bread baked in the old-fashioned way, and so the process was pecuniarily a failure.

Although the special action of this ferment is to produce alcohol from sugar, other changes go on with it and incidental to it, in the raising of dough, working of cider,—and indeed in all ordinary fermentation. In the dough a part of the starch is changed into a soluble form before any of it is changed to sugar, and other changes go on in the fermenting mass. It is commonly believed that fermented breads are more digestible than unfermented ones, and it seems to me very probable that this is so. Digestion itself is analogous to fermentation. Certain substances found in the juices of the stomach and the saliva are classed among the “*soluble ferments*,” and, indeed, are usually taken as their types. *Sauer kraut*, which is a partly fermented substance, is more easily digested than the “*slaw*” of which it is made. Even when the fermentation is carried on to sourness, many persons claim for it more wholesome properties. Sour cider, sour wine

require a cultivated taste to like them, but they are probably more wholesome as a whole than the sweeter article. Some of the peasantry of the old world who eat coarse sour bread claim for it high nutritive value, but I am content to follow my own education, and I prefer bread that is not sour.

As we are to have a paper on bread this evening, I will not follow this any further, but pass next to vinegar, where our subject has naturally brought us. The sour principle of vinegar is known to chemists as *acetic acid*. Vinegar is made by fermenting some liquid that contains either some kind of sugar or else alcohol. With us the most common basis is eider, and this, to my taste, makes the best vinegar, although those most used to wine vinegar prefer that. To make good vinegar, start with good "*mother*," which is the familiar name of the ferment. The material must be kept moderately warm. After the fermentation has practically ceased, and the liquid clears, it still improves in quality for a time,—it *ripens*, as we say. For family purposes an old wine-cask may be used, to which eider that has passed its first stage of fermentation may be added occasionally with satisfactory results. But for a good article we must not use a musty barrel, or the wrong ferment may work. Before I close I will have to tell you of other ferments which produce other substances. Thus far I have dwelt on the production of alcohol and vinegar. To illustrate what I mean I have brought with me two bottles. I will pass them both to the audience and let them be passed about, as they illustrate just what I wish to explain. The first bottle is partly filled with vinegar drawn from my own barrel of eider vinegar at home. You will all pronounce it of excellent quality, strong, pungent, aromatic, just the vinegar for nice pickles.

Eight months ago I took some of the "*mother*" from that barrel, washed it with clean water, then put it in this fruit-jar in a solution of clean white sugar in water. Now this, you would say, ought to have made nice vinegar. But besides the "*mother*" as a ferment, I added some fungus scraped from a rotten maple stump near my door,—not more than enough to make a mass half as large as a pea. But it con-

tained fungi that has produced other products than vinegar. I have watched the process from week to week, sometimes using my microscope, and now I pass it to you to show you how easily a vinegar may be spoiled. Along with the pungent odor of the vinegar is a peculiarly penetrating, stinking odor, disgustingly so, which lingers in the nostrils long after being inhaled. The wrong ferment has been at work. This is practically what spoils many a vinegar barrel—something is put in which contains some putrid ferment, and then the mischief grows. I don't know of any way to correct this but to begin anew, with a better barrel and fresh material. We have a similar thing with beer, which I will speak of here, as it illustrates the same principle. The celebrated French chemist, Pasteur, who has made ferments his life-long study, investigated the causes why some batches of beer turned out badly, and he found that it was produced by the wrong ferments getting in the wort and producing chemical changes which made the beer bad.

Now to return to vinegar. It is an important preservative, although it has been produced by a form of decay. There are many vinegars in market. In the old world much is made from wine. Some of the finest English pickles are put up in malt vinegar, where the infusion of malt is not made into beer but into vinegar, and an excellent vinegar it is. I once lived in a place where cider was scarce and dear, but whiskey abundant and cheap (it was before the war), and a single establishment made yearly many thousands of barrels of vinegar from diluted whiskey, fermented in large vats kept carefully at the right temperature. And so I might enumerate many sources. Those who live in cities and buy their vinegar, little know what is the basis of the vinegar they buy. I once knew a man who had a bar-room next his grocery, and the washings of his glasses, with the tinge of whiskey or rum, and the sugar left in the bottom, furnished the material to be worked into "pure wine vinegar" for his customers. These various sources give vinegars of different flavors, but the acid in all is the same. Vinegar is often adulterated with sulphuric acid (oil of vitriol), but this has nothing to do with fermentation.

Various summer drinks, such as root beer and small beer, are fermented with this same ferment, and all contain a little alcohol, but not enough to disturb the conscience or head of the most enthusiastic temperance advocate, although often enough to point the argument in the pettifogger's plea when defending some illegal sale of a stronger article.

Fermentation is often employed in the preparation of cattle foods of one kind and another. Grain, or cut hay, or other article is wet and allowed to partially ferment, and there is a wide-spread belief that such foods are more fattening, and I have known some examples where this seemed to be the case.

The next class of household applications is of

FERMENTATION WHICH IS NOT WANTED,

And is therefore to be prevented if possible. The most common application is in the canning of foods, but it also applies to other methods of preservation. I have said that some form of fermentation is the usual method by which the various products of animal and vegetable growth begin to decay. I have also said that anything that kills a living ferment immediately stops the chemical change it produces. A high heat is destructive to life. There are certain seeds, spores, and germs which can for a short time withstand the heat of boiling water (212° Fahr.), and still germinate, but they are relatively very few, and, so far as we know, no animal or plant during its adult or growing period can be actually boiled and still live.

Now, the whole art of canning foods is founded on the theory developed by science that fruits, meats, etc., will not decay unless some living ferment starts the process, and that all living ferments are killed by being thoroughly boiled. You know the process. It is essentially to thoroughly boil the material to be canned, to kill any ferment that may already be in it, put it into a jar or can that is heated hot enough to kill any germs sticking to it, and seal it up tightly while still hot, before any others can get in. If well done, the material will keep for years. If some germs lurk inside not killed, they

will do their mischief, and the stuff begins to "work." If it be fruit or vegetables, we can boil again and correct the evil; but if it be an animal substance, as fish or flesh, it cannot be saved. The ferments of flesh are what are called *septic* ferments, to be noticed later, and if the can of meat or fish begins to ferment, its flavor is spoiled before the change is discovered, and there are cases where both fish and meats have been rendered in a measure poisonous, producing sickness, because of such change going on after the can was sealed.

The success of canning, so far as preservation is concerned, depends entirely on effectually killing all the ferment-germs that are in the mass, or the vessel, and protecting the material from others getting in. We may boil a mass on the outside without the inside being thoroughly heated to the same temperature, if the material is not very fluid, just as we may have a piece of meat underdone in the inside although well browned on the outside. To the more effectually heat the material after being put into the cans, many devices have been resorted to. Some persons use *brine* instead of fresh water to set the jars or cans in, because brine can be made hotter than water. Some canning establishments have used a solution of *chloride of calcium* for the same purpose, which boils at a still higher temperature. I said that the sugar-ferments need some free oxygen to start the fermentation. The reason why it is well to have the can as full as possible before sealing, is to have as little air there as possible to aid the ferment in starting its growth.

The process of canning was a direct contribution of science to household comforts, and was not invented until the theory of living ferments was reasonably well demonstrated, although many applications of the same principle were used earlier.

I rather wonder that it should not have been invented and come in common use before it did. In the earliest days of my teaching chemistry, and long before my own school-days entirely ceased, while employed in a small agricultural school in Western New York, in 1851, to practically demonstrate the principle and show how chemistry could be applied to house-

hold uses, I "canned" several gallons of stewed tomatoes, using glass-stoppered bottles from the laboratory. It was a great success, and other families then began to use the process. So soon as the scientific principle was well demonstrated and known, the use sprung up in many places independently, and now the magnitude of the business is known only to those who have had occasion to look into the statistics of it.

Fermentation takes place easier in dilute solutions than in concentrated ones. The old process of making "preserves" and "sweetmeats" was founded on this; great quantities of sugar were added, and fermentation did not take place readily in the viscous mass. But even then accidents would happen, and the dainty morsel often would "work," to the great disturbance of the housewife, setting her into a mental fermentation also.

The boiling of new sweet cider and concentrating it to prevent its working is another illustration familiar to most farmers.

Sometimes it is desirable to check fermentation after it has begun. In bread we do it by baking; in fluids it may be done by boiling; but in wine or cider this would injure the quality, so various other means are resorted to. The fumes of burning sulphur, the use of *sulphites* and *hyposulphites* are often recommended, and are successful.

The third kind of "household relations of fermentation" is

THE SOURING OF MILK,

Which is a process of fermentation, and is due to the action of a special kind of fermentation, the ferment-fungus being of another species and producing *lactic* acid, as yeast produced *acetic* acid. If this ferment is prevented from growing, milk may be kept sweet a long time—I have no idea *how* long. Perfectly pure milk put into glass bottles which have been strongly heated will keep a length of time that seems incredible. All the means I have spoken of as preventing fermentation apply to the preservation of milk. Boiling, concentration, keeping in closed cans, and keeping cool are the most com-

mon methods. In condensed milk the same principle is applied that is used in condensing sweet cider. Many efforts have been made to preserve milk by the use of some chemical, and with some hope of success, but it is yet a question whether anything can be found which will kill a ferment-fungus in milk and yet be perfectly wholesome for man. The theory of ferments explains perfectly why dairies should be kept clean, why milk sours so much easier where the utmost cleanliness is not maintained, why the vessels must be so carefully scalded, and why milk should not be spilled about and allowed to remain.

The fourth class is known as the

SEPTIC FERMENTS.

They are the agents which induce putrefaction in substances containing more nitrogen. It has lately been found that putrefaction is accompanied with the development of ferments which are much more minute than those I have heretofore been speaking of, and about which there is more uncertainty. It is a question if even the most putrescible animal or vegetable substance would decay at all, at ordinary temperatures, without their aid. It seems to me to be pretty well demonstrated that if we prevent their growth there will be no putrefaction. Very many experiments have been made in late years pertaining to this subject, and just now no scientific subject seems of more importance to our race.

Among the more interesting and easily understood experiments are those of Professor Tyndall, which I will use for illustration.

There is always dust floating in the air, as we see when a beam of sunshine enters a dark room through a hole or crack. It is known that in this floating dust are the germs of many kinds of ferments, and particularly septic ferments. Prof. Tyndall prepared a number of boxes, a foot or two square, with small plate-glass windows in three sides. A number of holes were bored through the bottom, through which open-mouthed glass test-tubes were thrust, their open ends within the box, their closed ends projecting below the

bottom. These were tightly cemented in place. In the top of the box was another hole, over which was tightly fastened a thick but pliable sheet of india rubber. Through a slit in this was passed the long tube-like stem of a small glass funnel, which could reach the mouth of the test-tubes. There was a small vent by which the air could enter or leave the box with changes of temperature or of barometer, the air being filtered through cotton moistened in glycerine to remove any floating particles there might be in the air. The whole inside of the box is smeared with glycerine.

When all ready and in a dark room, a beam of very strong light is sent through the box from an electric lamp, and floating dust or motes may be seen in the path of the beam of light. If now the box remain quiet for a few days or weeks, the dust all falls to the bottom or sticks to the sides of the box, caught by the glycerine; and when a beam of light is sent through the windows in the box from the lamp, all is dark, the track of the beam cannot be seen; and in that way he found out when there were no longer any motes, and hence no ferment-germs floating in the air and liable to fall into anything put in them.

Now, by means of the long funnel passing through the rubber in the top of the box various putrescible liquids were introduced into the test-tubes; into one beef-juice, into another the juice of fish, and so on; the juice of various kinds of fish, flesh, fowl, infusions of vegetables as well as animals, mixtures of the infusion of turnips and cheese, cucumber juice, urine—in fact, the most putrescible things he could think of, to the number of some hundreds in all. Then the tubes were lowered into hot oil and all the liquids in them boiled to kill any ferment-germs they may have contained. They had all been very carefully filtered before being put in, so that they were perfectly clear. The whole were then kept in a warm room.

Now bear in mind the circumstances they are in. They are in perfectly free contact with the air inside the box, but this is pure air, perfectly free from motes and dust. If it is the contact with air alone that causes putridity, then they

ought to decay in the box as well as if outside. But none of them do decay. Weeks, months, and in some cases even years have passed, and the liquids remain as clear and sweet as the day they were put in, even the most putrescible of them. They may be watched, both through the tubes themselves and through the windows in the sides of the box. But once open one of the windows of the side of the box and let the common air of the room enter with its dust and motes, even for a moment, or but touch the clear liquid with the point of a needle which has touched a putrescing substance, and then soon the fluids in the tubes begin to grow cloudy and turbid, a pellicle forms on the surface, the microscope shows now that there are myriads of ferment-organisms, the fluid rapidly goes into putrescence, sometimes a mould grows over the surface, and in due time the liquid is resolved into a rotten, stinking mass.

This is but a sample of a great number of experiments which appear to prove that ordinary putrefaction is but a form of fermentation, caused by living ferments, of the class known as *septic* ferments. The canning of meats, fish, lobsters, etc., is a practical confirmation of this theory, and so far as I know, all methods of "*disinfection*" are also in accordance with it.

Popular language often confounds three distinct things: *Antiseptics* prevent decay; *disinfectants* stop decay already begun, and kill the germs which may induce further chemical decomposition; *deodorizers* clear away bad smells, whatever may be their origin, although sometimes the same chemical may produce all these effects.

To clear up the foul smells and disinfect decaying filth about the house, copperas (green vitriol or sulphate of iron) dissolved in water, in about the proportion of a pound of copperas to a gallon of water, is one of the safest and most convenient disinfectants to use about the house where there is no harm of staining. This is especially good for purifying privies, cess-pools, and other foul-smelling places. Carbolic acid is often used, but the sort which is most commonly sold in market smells badly of itself. Chloride of lime and burn-

ing sulphur are often used for fumigating, either to remove bad smells or to disinfect premises and rooms where there have been infectious diseases.

MOLDS.

Molds are very like ferments, both in their botanical character and chemical effects. The principal difference is this, that molds get the oxygen for their growth from the air, while ferments get it by decomposing the compound they live in. Some molds, if deprived of air, become true ferments, both in the way they multiply and the decompositions they produce. All molds produce decomposition, and most of you are familiar with many illustrations of where molds spoil the substances they grow on. The spoiling of ink, bread—in fact, almost anything about the house which molds, are examples too familiar to you all to need enlarging upon.

Anything which prevents the growth of mold preserves the substances usually affected by them. Oil of cloves, creosote, carbolic acid, corrosive sublimate, and various other solutions are used to preserve paste, ink, etc., and they act by preventing the growth of molds or ferments. Molds and ferments require two things, something to live on, and moisture. The first we are very apt to have somewhere about the house; the second we should not have about the house if we would live in health.

If a cellar is too damp, it will be moldy, and should be dried in some way. If it is reasonably dry and still molds much, it is a sign that it is badly infected with germs, and has most probably some unwholesome condition which has escaped notice. Therefore cleanse it thoroughly, be sure it is dry, ventilated, and keep well whitewashed. Fumigating with burning sulphur often helps a moldy cellar. Burn a pound or two of sulphur in a kettle of burning coals.*

I have reached the limit of my hour, yet I will take a few

* I will mention here, although it has no relation to fermentation, that the fumes of burning sulphur is perhaps the most convenient and effective means of getting rid of the odor of skunks, sometimes so very annoying about the farmer's premises.

minutes more to speak of another class of phenomena, which most probably belongs to this subject, but where the theory has not yet been proved. I refer to what is best known in common language as

THE GERM THEORY OF DISEASE.

There is a large class of diseases which present phenomena so like those of fermentation that the resemblance was noticed even by the ancients, and from this long-observed resemblance they are called *Zymotic* diseases, a name derived from the old Greek word meaning fermentation. Some of them, like small-pox, plague, typhus and scarlet fever, are contagious. Some are communicated only by inoculation, as we see in ordinary vaccination. Others, like typhoid fever and cholera, are not contagious, but may be communicated through drinking-water or other substances taken into the stomach. Still others, like yellow fever, are not communicated by means of drinking-water, and are not contagious, and yet they do spread by some form of infection, the precise character of which is as yet undetermined. Some diseases of this class, like the chicken-pox, are of little importance; but others, like the cholera, yellow fever, plague, and small-pox, sometimes become the most dreadful pestilences which afflict our race. And not our race alone, for the brute creation has its pestilences and plagues also, which are just as destructive, just as deadly, and which belong to this same class of diseases.

In the few minutes I have left, I can glance at only some of the facts and reasons we have for believing that these diseases are due to a kind of fermentation.

In the first place, each must have a specific something to start it. We do not have the measles, nor the cholera, nor small-pox, without being infected with something which comes from beyond ourselves. The disease does not start in us without the infection. As in fermentation, a something is required to start the action, but when once started, it then goes on without any further addition of this infecting substance.

In the second place, just as fermentation runs a definite

course and then stops, so these diseases do. First each has a quiescent stage, then later a disturbance with a rise of temperature (all these diseases are accompanied with fever in their active stages), then a decline. They run a definite course and last for a somewhat definite period. A man may have the rheumatism or the dyspepsia for forty years, but he cannot have the measles, nor the small-pox, nor typhoid fever for even one year. They run their course (unless the victim dies) and then cease. Moreover, with many of them a man has the disease but once, just as a barrel of cider ferments but once.

In the third place, the chemical effects in the system are very like those of fermentation. A man has the cholera and a rapid chemical change goes on in his blood and juices; they lose their usual characters at a fearfully rapid rate, and they are cast forth from the system in a state of active decay entirely unlike any of the dejections in health. And something of the kind takes place in all these diseases—something is attacked, and some definite and specific change is produced. The chemical change may show itself in the skin as in small-pox, or in the intestines as in typhoid, each disease having its own special form of destruction just as each ferment produces its own special decay.

In the fourth place, the chemical characters of the virus of contagion are like those of a living organism, but entirely unlike those of a mere chemical poison. For example, compare it with white arsenic. A certain dose of arsenic is required to kill, say two or three grains. When the poison is swallowed it begins its work immediately, and so soon as enough is absorbed into the system the victim dies; it may be in a few minutes if the absorption has been rapid enough, or it may be after some days, but in either case with the symptoms of a disease. But this disease cannot be communicated to any one else unless the arsenic is extracted from the dead body, and then we would find no fresh poison produced, no more arsenic than we began with. Moreover, with poisons, as a rule, the larger the dose the more speedy its action, if it be retained. And so also of strychnine, and

prussic acid, and the many "*poisons*" known to chemists. Now all this is very unlike the virus of contagion. A minute speck of small-pox virus, what we could hold on the point of a needle, is introduced by a scratch into the blood of a man who has never had the disease. It does not show its effects at once, but for a time it is apparently dormant, as a seed seems to be in the ground before it sprouts, or an egg is before it hatches. After a somewhat definite time the disease appears and runs its course, during which large quantities of fresh poison are produced with which many more persons can be inoculated, and these in turn produce still more of the virus, until in a comparatively short time there would be enough to infect the whole human race. The spread of typhoid fever, cholera, the plague, and all the others of this class of diseases shows essentially the same class of facts. Now all this is entirely unlike any chemical poison known, but it is very like a living ferment, growing and multiplying in the juices and fluids of the creatures infected, living on the organic substances they contain, changing the characters upon which their health depends, bringing disorganization, decay, and destruction of the tissues, and, it may be, death.

In the fifth place, the physical character of the infection and its relations to heat are more like those of a living ferment than a dead chemical poison. A great many interesting and instructive experiments have been made on vaccine, the virus of small-pox, sheep-pox, glanders, and on the virus of various other contagious diseases.

In all cases tried, the virus is killed by boiling, just as the living ferments are, but they usually stand a much greater degree of cold than of heat. They also lose their infective properties with age, and this is hastened by free exposure to the air. The virus of different diseases varies greatly in this last respect, but as a rule, the same treatment which will prolong the vitality of seeds and of living ferments, will also prolong the vitality of the virus of contagion.

The virus of the sheep-pox (and of other poxes, so far as examined,) is produced in the "*matter*" or *pus* of the sores or *pustules* peculiar to these diseases. This *pus* consists of

an albuminous liquid having very small particles diffused through it. The two can be separated from each other, and then the fluid without the particles will not produce the disease, but the particles without the fluid will. That is, the infective principle is in the particles and not in the liquid, just as in wort, vinegar, etc., the "infection" is in the yeast-cells and not in the liquid in which they are suspended. When the particles from sheep-pox (or vaccine) are used to inoculate a new subject, the disease is communicated, and fresh particles are formed in the new victim, just as fresh yeast-cells are produced in a new barrel of cider. But these particles in vaccine and in sheep-pox, etc., are so very small and so nearly transparent, that the best microscopes tell us little about their physical characters more than their mere existence. It does not prove that they are specific living cells.

In the sixth place, the most successful methods for the prevention and control of zymotic diseases are conformable with the theory that the infection by means of which they spread is a *living* infection, call it a germ, or spore, or cell, or ferment, or what you will. The disinfectants and conditions which experience has shown to be the most efficient in staying contagion or purifying places from its effects are the very things which we know effectually destroy the life of the actual ferments with which we are acquainted.

In the seventh place, it is abundantly proved that some of these very diseases are produced by living organisms which belong to the class of septic ferments. They have been very carefully studied, the history and development of the living ferments which produce them have been traced, and figures of them may be seen in various works on sanitary science. The relapsing fever in man, a very contagious disease in some countries of the old world, is now known to be due to such a cause, and several other diseases of man might be cited. The "pig-typhoid" in swine is another case, the "febrine" or silk-worm disease is another, and a very considerable list might be prepared where the proof is complete and convincing. In some cases, the infection is a true ferment which

can be cultivated in certain animal fluids, outside of the animal body, for generation after generation, and then this artificially-grown ferment may be used to infect fresh animals, who in turn have the disease just as if they had taken it in the natural way.

Last, but not least, the studies and discoveries of each succeeding year point stronger and stronger in this direction as the explanation of the phenomena. That is, as our knowledge increases, the reasons increase for believing this theory to be the true one, and the objections diminish. I certainly think that it furnishes the most plausible and philosophical explanation of the facts observed in this class of diseases, and hope, when our knowledge is further extended, that we will be able to control even those pestilences which have so long been the terror of our race. The main objection to the theory is that it is *not proved* to be true with the great majority of the diseases of this class. It is *proved* of only a part of them; with the remainder it remains as yet but an hypothesis.

Its household applications are too obvious. This class of diseases is known to sanitarians under the popular but unsavory name of "*Filth Diseases.*" With some of them it is believed that their germs are actually produced in decaying filth, with others that they are distributed through filth, and it is known that all are aggravated in their severity by filthy surroundings. If this theory be true, it gives us an inkling of why human excrement is so fearfully dangerous when it contaminates wells, or other drinking-water; it gives a reason for boiling or filtering impure water before use for drinking or in food, and of the purifying action of heat generally; it strongly indicates the necessity of keeping decaying garbage and slops away from our houses; it gives us hints about the purification of sick rooms and other foul places, and gives a philosophical basis for the sanitary care of our domestic animals, ourselves, and our homes.

The CHAIRMAN. An opportunity will now be afforded for any questions which any lady or gentleman may desire to ask. I presume Prof. Brewer will answer them very cheerfully.

Mr. AUGUR. There is a trouble that sometimes occurs in certain neighborhoods, called "stringy bread." What is the cause of it?

Prof. BREWER. "Stringy bread" and "ropy milk" both come from a fungus analogous to a ferment. When a bakery or a house becomes infected in that way, it is a pretty difficult matter to get rid of it. I do not exactly know what is the best way. Very similar to that, but a great deal rarer, is "bloody bread," in which particles of bread are found that are perfectly red. I have only seen two cases of that. I had one specimen in which pieces of bread as large as your fist were blood-red. It is caused by a fungus which is very difficult to get rid of after it has started. The atmosphere of a house may become infected with the germs, and it is very difficult to get rid of them.

Mr. PERKINS. Where milk and cream are infected by this fungus, is butter affected in any similar way by any kind of parasitic fungus?

Prof. BREWER. I do not know that it is. I never heard of it. The changes which take place in butter spring from another cause. It is a true chemical change which takes place. There may be some such change take place in butter. If so, I have never seen it proved.

Mr. OLCOTT. I would like to ask the professor if he ever happened to make a study of the mold in "ropy cheese."

Prof. BREWER. That comes from "ropy milk." I will say here, that the Experiment Station has undertaken to investigate the subject of "ropy milk." It looks as though it resulted from unsanitary conditions about the place, perhaps in the water. That is what Prof. Law thinks it comes from. In the next report of the Experiment Station, there will be a paper by Mr. Sedgwick on that subject, in which he will detail all that he knows about the matter.

In this connection, I will say a word about the Experiment Station. I have been asked about the analyses performed there. We profess to analyze fertilizers for any farmer in the State who is buying them. If he has any fears that he is

getting commercial fertilizers that are not what they should be, and wishes to ascertain their purity, if he will send us samples, we will analyze them. If half a dozen or a dozen in one neighborhood, should all send the fertilizers of one manufacturer at the same time, of course it would be unnecessary to analyze them all. These analyses are made free for the benefit of the farmers of the State who are using commercial fertilizers. If any of you want information on that subject, or upon any other where science can be brought to the aid of agriculture, if you will drop a line to the "Experiment Station, New Haven," you will receive such information as may be in the possession of the persons who have charge of the work. This is done free of charge to farmers.

Mr. HUBBARD. What bearing has the subject which Prof. Brewer has been discussing upon the controversy which arises every summer in regard to curing hay? I presume that every one who reads the papers knows that when summer comes, some one will write that hay ought to be dried so thoroughly that it will not heat; and thereupon somebody else says that it ought not to be dried so much as to prevent its heating a little. I understand that heat in a haymow is fermentation.

Prof. BREWER. Analogous to it.

Mr. HUBBARD. I understand that it promotes digestibility, and therefore it is a fair presumption that a larger portion of the hay is rendered more digestible when it is put into the mow with some moisture in it than when it is perfectly dry. Therefore I have taken some comfort from the professor's remarks. I have put in my hay when it was so moist that the water stood in drops on the mow, and I found the hay sweet and palatable. I should like to have the professor's opinion on that subject.

Prof. BREWER. I am inclined to think you are right, provided the hay does not mold. Up to the point where it begins to get moldy, I believe it may be as moist as you please.

Mr. HINMAN. It seems to me that we could get at the solution of this question. Mr. Gold told us the other day

that our corn meal must be kept in a state as nearly as possible entirely free from fermentation. Our friend, Mr. Olcott, has some very good corn meal. If we could get the Experiment Station to see whether his corn meal can be improved for human food, so that we should like it better, and it would be more digestible, by any amount of fermentation short of molding, there would be some chance of arriving at definite results, instead of any theory that we may have now.

Mr. AUGUR. I would like to ask the Professor if the Experiment Station has made any examinations in relation to adulterations of food.

Prof. BREWER. Of cattle food, yes. I do not recollect that they have of any other food. I think, while there is a great deal of adulteration going on in human food, that matter has been very much exaggerated by the sensational statements which have appeared in the papers. I have examined some things myself that were liable to be considerably adulterated. There is a great deal of adulteration of the kind that affects the pocket, but does not affect the health, like the use of dextrose in sugar, or oleomargarine in butter. These frauds affect the pocket, undoubtedly. I do not know that these adulterating substances are necessarily bad for the health.

Mr. AUGUR. What I had particularly in mind when I asked the question, was this: A confectioner told me, within two or three months, that ground marble had been used quite largely in the manufacture of candy, and that cheap candy almost invariably contained a certain proportion of ground marble.

Prof. BREWER. As a general thing, the adulteration of candy is more harmless than that. Confectioners put in a great deal of flour, and I think I have seen candy containing gypsum, but not in this State. The white clay called *terra alba* is reported as used in candy. Pulverized slate is largely used in the manufacture of paper, to make it a little heavier.

Mr. WINSLOW. Is a cellar a good place for vegetables?

Prof. BREWER. Yes, if it is a good cellar.

Mr. WINSLOW. What is "a good cellar"?

Prof. BREWER. A good cellar is one that is dry and cool—never gets wet.

Mr. WETHERELL. I would like to inquire what effect the souring of milk has upon its nutritive qualities?

Prof. BREWER. I do not suppose it affects its nutritive qualities at all, but I do not know how it affects its digestibility.

Mr. PERKINS. Do you consider that a stream of water running through a cellar is a disadvantage to the cellar? I have known of such cases, and never heard any complaint that the cellars were injured in any way.

Prof. BREWER. I should not think that would be specially bad. I never lived in but one house that had a spring in the cellar, and in that case the water did not run through. I cannot say that was a success as a cellar. The trouble about cellars keeping things sweet very often arises from the filth that gets on to the bottom of them, in one way and another, which does a great deal of harm.

