lime-kilns, sand-gatherers, rolling-mills for structural and roofing iron in sheets and beams, for tinners and roofers, and the thousand other trades engaged in construction, not only of the 14,000,000 new homes, but of the markets, stores, warehouses, post-offices, court-houses, city-halls, jails, penitentiaries, etc., necessary in the administration of an additional population equal to all that exists now on the northern continent! What will be the work of providing, and delivering at every house, three meals a day, and every day, for each inhabitant thereof? M. C. MEIGS.

BACTERIA IN MILK AND ITS PRODUCTS.

DURING the past year, investigations on the bacteria of milk have been carried on in the laboratory of the Agricultural Experiment Station, Mansfield, Conn., under the direction of H. W. Conn, professor of biology in Wesleyan University. The following is a brief summary of some of the more interesting results of this work.

The term "bacteria" is used to comprise a class of organisms found abundantly in the air, water, and soil, and in plants and animals. As commonly employed, the term includes a large variety of organisms, which naturalists divide into the three classes, bacteria, yeasts, and moulds. The term "microbe" has been recently introduced to cover this same ground, and is for many reasons preferable. The plants included under this head are exceedingly numerous, and the part they play in nature is of great importance. They multiply with the greatest rapidity, a single individual in the course of a few days being able to give rise to millions. While they are thus growing and multiplying, they produce great changes in the medium in which they grow. All fermentation (such as raising of bread, fermenting of beer, cider, etc.), putrefaction and decay (such as rotting of potatoes, decay of wood, etc.), are produced by the organisms here included. They are of immense value as well as injury. Through their agency, dead animal and vegetable matter is decomposed, and prepared to be incorporated with the soil and to be used as food by plants. It is doubtful if vegetable life could be long continued without their aid. On the other hand, they cause disease in plants, and disease in animals; many of the most dangerous diseases, as cholera, typhoid-fever, consumption, hog cholera, bovine tuberculosis, chicken cholera, etc., being produced by these disease germs. These organisms are extremely minute and simple. They are commonly not more than one two-thousandth of an inch in length. In shape they show three chief varieties, which may be compared to a lead-pencil, a ball, and a corkscrew. To-day they are universally regarded as plants, in spite of the fact that many of them are endowed with motion.

Methods of Experiment.

The method of experiment has been that common in modern bacteriological research. For culture solutions the ordinary beef peptone solution, stiffened by gelatine, or more commonly by agar-agar, has been used. For most of the experiments with cream, "ripened cream" has served as a starting-point. In some cases sweet cream has been ripened in the laboratory, and examined each day, but more commonly specimens of ripened cream have been obtained from the dairy of a butter-maker and directly studied. Plate cultures have been made from the cream, usually with agar-agar, since the organisms found grow in this medium most readily. From the various colonies found in the agar plates, needle cultures have been made in gelatine. Subsequent purification of the organisms has been made in the ordinary way, by transferring from tube to plate, and plate to tube, until the bacteria were separated from each other in pure cultures.

For further experiment, milk has been sterilized in test-tubes. This can be done at a temperature of about 70° C., but it has been found more convenient to put the tubes for a few minutes in a steam sterilizer. Sterilization upon three successive days is commonly sufficient, but in a few cases milk was found to change even after such treatment. The sterilization of cream has been accomplished in the same way. There is more difficulty in this, however, for the cream is apt to form a thick layer on the surface, with a thin watery layer below; and this occurs even in cream that is thoroughly sterilized. In the experiments upon the action of the different bacteria upon milk, the inoculations have been made, and the tubes allowed to remain at the temperature of the laboratory for a day or two. If no change occurs, they are then placed in a thermostat at a temperature between 30° and 35° C., and allowed to stay there till they have produced their effect upon the milk.

Accompanying all of the experiments upon milk and cream, a series of experiments have been carried on with the same organisms upon three different solutions. One was the ordinary beef peptone solution without gelatine; the second, the same solution, to which a small amount of milk-sugar had been added; and the third, the beef peptone solution, with the addition of glucose instead of milk-sugar.

Inasmuch as the object has been to determine the general effect upon milk and its products of the various bacteria present in the air, it has been necessary to work with all the numerous species that have been found in ripened cream. This has necessitated a very large number of experiments, continuing through eight months. The account of these experiments, which, to be in any way useful, will require a large number of pages of detailed description of individual species of bacteria, as well as their action and effects, is reserved for the next annual report of the station. At present it is designed to give only a brief summary of the most important facts concerning the relation of bacteria to milk and its products. For this reason the following remarks include results of the work done at the station, and of other investigators as well, and some conclusions derived from them.

Bacteria in Milk, Cream, and Butter.

Milk is a medium in which bacteria grow with the greatest readiness. Experiments have thus far given indication of some thirty or forty species of bacteria that are floating in the air in this vicinity, every one of which is found in cream, and grows with the greatest facility in milk. Probably none of those which were studied produce disease, and hence are called non-pathogenic. The researches of others have shown that many of the disease (pathogenic) germs also find in milk a favorable medium for growth. According to experiment, cream seems to be even a better medium for the growth of bacteria than milk; for it will keep longer without putrefying, and thus allow some of the slower-growing species to develop. Butter is not a good medium for the growth of bacteria, apparently because they require for their development a certain amount of albuminous material, of which good butter, being mostly fat, contains only a minute amount. Bacteria have, however, always been found present even in the sweetest of butter, but usually in small numbers. When for any reason they become very numerous, the butter becomes tainted.

If milk, cream, or butter is kept free from bacteria, the ordinary changes do not take place in them. For example: the bacteria in milk can be readily killed by heating the milk to a boiling or even lower temperature for a few moments upon three successive days; and then, bacteria being excluded, the milk is found to keep sweet indefinitely. Killing the bacteria by heat is known as sterilizing. If a lot of milk is thus sterilized, and then a few of any particular species of bacteria are put into it, the effect which this species produces upon the milk can very easily be determined. It is in this way that the experiments have been made.

Milk and cream under ordinary conditions cannot be kept free from bacteria. Milk drawn from a healthy cow is free from them, but they may get into it when the milk is in contact with the air during milking. A single experiment will indicate the difficulty of keeping them out of milk. Eight test-tubes were washed perfectly clean, and plugged with a mass of cotton. They were then heated very hot until all living matter in them was killed. These were taken into a milking-yard, and, after the teats of the cow and the hands of the milker had been carefully washed, the cotton plug was taken out and milk drawn directly from the cow into the tubes, and the cotton plug replaced. Of these eight tubes, seven soured in a few days, and many bacteria were found in them. The other remained sweet for a long time, but eventually it also changed. From this experiment it is seen that in the few seconds in which it was exposed to the air the milk was contaminated with bacteria. A very common source of contamination of milk is from

vessels in which the milk is placed. These, unless recently washed in boiling water, contain bacteria clinging to their walls. These bacteria begin to grow as soon as the milk gets into the vessels, and in a few hours will multiply so as to be extremely abundant.

Number of Bacteria in Milk. — Different Species.

The number of bacteria in milk will depend chiefly on three things: 1. The cleanliness of the vessels; 2. The temperature of the milk, warmth being favorable to their growth; 3. The length of time that the milk has been standing. Ordinarily the number of bacteria in the air is of comparatively little importance, unclean vessels being the great source of contamination. If, however, the vessels are perfectly clean, the number of organisms in the air becomes the important factor. In cream which has been allowed to "ripen" for a few days, the number is extremely great. In the specimens of ripened cream which we have examined, from 10,000 to 100,000 individuals have been found in a single drop, the latter number being usually nearer the truth than the former. Even under conditions most unfavorable for their growth, in a cool cellar during the winter, 12,000 have been found in a single drop. These are capable of multiplying with the greatest rapidity, producing hundreds of thousands in a few days.

Not only is the number of individuals very great, but the number of different species is considerable. Some thirty or more different species of bacteria have been found during the winter in specimens examined in the laboratory. No single specimen of cream contained them all, but each contained several species.

The number of bacteria present has, however, no significance until we know something of their effect. Some are harmless, some are hurtful; some affect cream, milk, and butter injuriously, and others do not. The effect produced by most of these organisms upon milk is striking.

Of the large number of organisms found in milk, two or three seem to be characteristic. The first is the one that produces the ordinary souring of milk (*Bacillus acidi lactici*). This organism, upon being introduced into sterilized milk, grows rapidly, and soon breaks up the milk-sugar that is present into either lactic or acetic acid and carbonic acid. The acid thus formed causes the milk both to curdle, by hardening or coagulating its albuminous matter, and to acquire its well-known sour taste and odor. This organism is very abundant in the air in warm weather, but in the winter seems to be much less abundant: indeed, it can at times almost be said to be absent. Milk has been kept in an open dish in the laboratory, during cold weather, for two weeks without its going through the characteristic changes of souring. It finally curdled, but with a peculiar odor of decay, and did not sour in the typical manner at all. The vessel in this case was absolutely clean, so that the air was the only source of contamination. The changes which did take place were produced by bacteria other than the common sour-milk bacterium, this one not seeming to be present at all. The fact that the typical souring was thus prevented shows that the common sour-milk bacterium was not present in the air at the time, at least in any great quantity. Such an experiment would not succeed in the summer.

A second species almost always found in milk is *Oidium lactis*. This produces no important change in milk. It grows rapidly, but does not cause the milk to sour or curdle. Besides the two mentioned, a large number of other species have marked effects upon milk.

Action of Different Kinds of Bacteria in Milk.

As concerns their action, we may divide them into four classes: 1. Some, like the bacteria of sour milk, cause the milk to sour by breaking up the milk-sugar into lactic or acetic acid and carbonic acid: curdling of the milk results. 2. Many produce the same result, but only at somewhat higher temperatures. At ordinary temperatures, they grow, but do not curdle the milk; in a warm oven, however, the milk will soon curdle. Accordingly, these would sour and curdle the milk in summer, but would not do so, or would do so less readily, in winter. The temperature and time required to produce the curdling differ with different species of bacteria. 3. Some do not have the power of breaking up milk-sugar, do not produce any acid, and do not coagulate the milk. The milk remains liquid, and sometimes becomes decidedly alkaline. 4. A few species curdle the milk, but produce no acid, the milk becoming alkaline instead. The majority of bacteria of milk and cream which have been experimented upon produce a souring and curdling of milk at some temperature. Experiments have also indicated that the action in all these species is somewhat similar; i.e., the breaking-up of the milk-sugar into an acid and some other product. But, although the action is thus fundamentally the same, the details of the action vary with each different species of bacteria.

The curdling is very different in character with different species. In some cases a hard curd and a clear liquid are formed; in others a curd is formed, but no liquid is separated from it; in still other cases the whole milk is turned into a semi-gelatinous mass. Sometimes the curd is easily broken or cracked, like the curd of common milk; in other cases it is very tenacious, sticky, and slimy. Sometimes the curd is dissolved in a few days, and the milk is left as a clear and almost transparent liquid. Here the caseine seems to undergo a change similar to digestion; i.e., conversion into peptones.

In connection with the curdling, there also arises in all cases a characteristic odor, which differs with different species of bacteria. There is a sour smell, a smell like sour bread, a smell like soft-soap, like salt mackerel, like a pig-pen, like the barnyard, and in many cases a smell of putrefaction. Besides these, there are others that cannot be described because of the lack of words in our language to distinguish odors. As far as the studies have gone, the effect of each species of bacteria upon the milk seems to be different from all others. The dairyman or the housewife would in most cases say that the milk had soured, but careful study shows that in reality the different bacteria do produce effects differing to a greater or less extent. The results of the experiments seem to indicate that what is commonly known as the souring of milk is not always caused by the common sour-milk bacterium, as has been usually supposed, but is frequently produced by others, and that the products formed are different. Particularly is this true in winter.

Bacteria in Cream.

Experiments were undertaken in the expectation that the so-called "ripening" of cream would prove to be a definite change due to the growth of bacteria. Having found that the souring of milk is less simple than had been supposed, one is prepared to find that the "ripening" of cream is also a complex process. It is not easy to say just what is meant by "ripened" cream. In ordinary farm practice, cream is usually allowed to stand for a few days before churning, when it becomes somewhat thickened, and acquires a pleasantly sour odor. In the creameries the cream is also ripened, though for a shorter time, and it does not become so thick or so sour. That the ripening is due to the growth of bacteria there can be no doubt. Ripened cream always contains these organisms in almost inconceivable abundance. In some places the ripening is hastened by adding a little sour cream as a "starter." This simply means the addition of a large number of bacteria, which of course hastens the process. Sometimes an artificial starter in the form of an acid is added. This practice proceeds upon the supposition that the ripening is due to the formation of an acid, which is probably a secondary matter. It is doubtful if this kind of a starter has any definite value.

By successive heatings, specimens of cream have been deprived of all bacteria, and it is then found that the cream remains unchanged indefinitely. In these specimens of sterilized cream have been planted the various species of bacteria that have been experimented upon. All of them grow well in the cream, and each has its characteristic effect; but no one of them has yet been found to produce exactly what would be called ripened cream. Some curdle it; some cause it to putrefy. From all of the experiments it may be concluded that the ripening of cream is a complex matter. The souring is apparently due to a process similar to the souring of milk; the thickening, in part to the curdling of the small amount of milk left with the cream, and in part to immense numbers of bacteria that develop. Another important factor in the ripening of cream is the decomposition of the albuminous matter present. In general we infer that different kinds of bacteria assist in the ripening of cream, but doubt whether any one has such a definite

relation to it as the sour-milk bacterium has to the curdling of milk.

Objects of the Ripening of Cream.

There seem to be two chief objects in ripening cream. It is a matter of experience that the butter will separate more readily from ripened cream, and the churning therefore be easier; and it is believed by many that the butter made from ripened cream will keep longer than butter made from sweet cream. A simple explanation is suggested, if not warranted, by the facts at hand, and may be of interest to butter-makers. Dr. Babcock of the Wisconsin Agricultural Experiment Station has pointed out, that, shortly after milk is drawn from the cow, there appears in it a fine, inappreciable network of fibres, which produce in the milk a slight thickening somewhat like the clotting of blood, except that it is much less marked. This, which Babcock calls "fibrine," is of an albuminous nature, and will readily putrefy. When the cream rises to the surface of the milk, a considerable quantity of this so-called fibrine is entangled with it, and is skimmed off with the cream. The butter-globules are enclosed in this fibrine, and in churning they must be shaken out. Now, in the time that the cream is ripening, the numerous bacteria are at work upon this albuminous fibrine, feeding upon it and decomposing it. The breaking-down of the fibrine is also assisted by the acid that is formed by the bacteria, for it is a well-known fact that acid will greatly assist in the solution of materials similar to this fibrine. After the fibrine is thus partly dissolved by the action of the bacteria, the butter-globules will much more readily be shaken free from them, and churning be made easier.

The keeping-property of the butter is easily explained by the same considerations. There is no doubt that bacteria are the cause of rancidity in butter. Bacteria cannot live upon pure fat, but require for food a certain amount of albuminous matter. It follows that the more albuminous matter there is in the butter, the more readily will they grow, and the quicker will the butter become bad. If the cream is churned before the albuminous fibrine has become decomposed, the butter will usually contain more of the fibrine than will butter made from cream after the fibrine has decomposed. Butter made from ripened cream will naturally contain more bacteria than that made from sweet, since the ripened cream itself contains them; but this is a matter of less importance than the ability of the bacteria to grow and multiply in the butter, and, for reasons above stated, this they can more readily do in butter made from sweet cream.

From this it would seem that the value of ripening cream depends upon the albuminous fibrine that is present in the cream; and any process that diminishes this diminishes the necessity of ripening, at least so far as concerns the two objects above mentioned. Babcock has shown that the quicker the cream rises, the less will be the amount of the fibrine entangled with it; and that, when cream is separated by a centrifugal machine, a considerable part of the fibrine collects on the drum of the machine, and less in the cream. It would seem, therefore, that there would be less need of ripening centrifugal cream than that raised in the more common way.

A third object attained by ripening cream is to give a certain flavor to the butter which is not obtained in butter made from sweet cream. This is a matter of as much importance to butter-makers as either of the other two, for the value of butter usually depends more upon its taste than upon its keeping-properties. But the relation of the taste of butter to the ripening of the cream, and to the method of handling the butter, is a matter too vague and indefinite at present to warrant definite statements.

Cleanliness in Dairying.

It must be remembered that many bacteria are so minute that thousands of them might occupy less space than the point of a needle; that they multiply so rapidly that millions may be produced in a short time from a single one; that organic (animal and vegetable) matters, including many forms of what are ordinarily called dirt, are media for them to grow in; that milk is especially adapted to their development, and the most minute quantities of it may serve for their dwelling-place, and furnish food for their rapid growth; and that they are sure to adhere to the surface or cling in the joints of vessels that have contained milk. Bearing all of these facts in mind, the necessity for thorough cleansing of all vessels used in handling milk is apparent. To wash such vessels so that no particles of dirt will remain on the surface or in the joints is extremely difficult. It has been frequently demonstrated that no amount of washing in cold or even warm water will remove all bacteria. It is necessary to use boiling water, and to leave it in the vessels for a considerable time, to destroy the active forms of bacteria that are sure to be present. Even though the active forms may be killed by boiling water in the course of a few minutes, their spores, which correspond to seeds, will resist boiling temperature for a long time. The danger of contamination from spores is not so great but that it may be neglected for all practical purposes, and, unless the vessels are contaminated with some dangerous bacteria, a thorough washing in boiling water is sufficient. But vessels in which milk is to be kept cannot be properly cleaned by pouring boiling water into one, allowing it to remain there for a few minutes, and then pouring it into another, and making one heating of the water suffice for the cleaning of several vessels. The last ones thus treated will not be much cleaner, so far as bacteria are concerned, than if they were washed with cold water. To clean vessels thoroughly, it is necessary to use a higher temperature than that of boiling water, which can be readily obtained by putting them for a few minutes in a hot oven or on a hot stove. If this is thoroughly done, there is no danger of contamination of milk from the milk-vessels.

The use of sal-soda in washing milk-vessels is advantageous, because it acts chemically upon fatty matters (grease), and thus helps to remove them and other materials which adhere to the vessels with them. In like manner, the use of "live steam" to "dry" vessels after washing has the advantage of sterilizing them; i.e., killing the bacteria by the highly heated steam.

BOOK-REVIEWS.

The Ice Age in North America and its Bearings upon the Antiquity of Man. By G. F. WRIGHT. New York, Appleton. 8°. $5.

IT may perhaps be questioned whether the time has yet come for a popular presentation of the glacial theory in so detailed a form as is given in Professor Wright's book, for it is still a matter upon which much investigation must be expended; but, on talking with teachers and intelligent readers who have not access to the scattered literature of investigation, it is apparent enough that they greatly need a compendium of the results of glacial study as it now stands, as they have no sufficient comprehension of its remarkable conclusions. This book on the ice age in North America will therefore have a wide reading, and, if its readers note carefully the expressions of doubt as well as the expressions of fact, it must be serviceable to them. Professor Wright's style is entertaining, and he brings together a large and well-selected body of description from the works of pretty much all the glacialists in the country. The illustrations are excellent, and the citations are numerous; but, for the sake of historical precision, it would have been better to add the date of publication of the writings of others, and it might have been advisable for the author to place the "Report of the Ohio Geological Survey," and several other papers, before his own in the extended list of essays on our terminal moraines (p. 139), to which the studious reader is referred.

The book opens by discussing the nature of glaciers in general, and illustrates this by descriptions of our glaciers in the West, and by the author's account of his observations on the Muir glacier in Alaska in 1886. Glaciers in Greenland and other parts of the world are then allowed two chapters before taking up the indications of extinct glacial action, to which the rest of the volume is devoted. Some of the more important headings are, "The Glacial Boundary and Terminal Moraines," "Glacial Erosion, Transportation, and Deposition;" "Contrasts of Pre-glacial, Glacial, and Post-glacial Drainage;" "The Date of the Glacial Period and its Relation to the Antiquity of Man."

If one may judge by the small attention given to glacial topography in our ordinary text-books on physical geography, it may be