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ESSENTIALS OF

MILK HYGIENE

A PRACTICAL TREATISE ON DAIRY AND MILK INSPECTION AND ON THE HYGIENIC PRODUCTION AND HANDLING OF MILK, FOR STUDENTS OF DAIRYING AND SANITARIANS

BY

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TRANSLATED AND AMPLIFIED

BY

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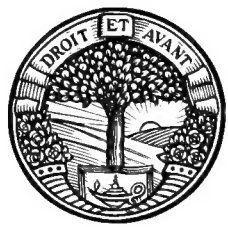
ILLUSTRATED



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AUTHOR'S PREFACE.

(TO THE ENGLISH EDITION.)

In the hygienic movement of the times the control of the production and handling of milk has not been given a prominent place. But the significance of this subject is now plain and everywhere efforts are being made to institute such a control or to improve it. The efforts of cities to secure a wholesome supply of milk must of course differ and be adapted to local conditions, but they must all be governed by the same principles and rest on exact knowledge of the composition of milk and of the dangers that are to be avoided.

In the preparation of this book it has been my hope that it would not only be of use to my Danish colleagues, but that my colleagues in other countries would find it to be of service to them. For this reason I published a Danish and a German edition simultaneously and for the same reason I have been very glad to grant Prof. Pearson's request for permission to prepare an English edition.

C. O. JENSEN.

TRANSLATOR'S PREFACE.

THE production of market milk is a rapidly growing industry. The demand for milk in cities is continually increasing and there is reason to believe that the rate of increase will advance.

The milch cow transmutes the pasturage and forage of the farm into edible protein, lactose and fat—into units of nutriment for man—at less than one-half the cost of similar units in beef produced by the steer. Milk is not only the most economical but, when pure and undefiled, it is among the most wholesome and it is the most easily digestible of all foods of animal origin. These are the strongest possible reasons for its extended use.

On the other hand, there is no other food that, under ordinary conditions, is so exposed to contamination, that is so easily contaminated or that so fosters contamination as milk. Hence the necessity for the study of milk hygiene.

The subject is a broad one. Milk hygiene involves some knowledge of the physiology of cows, especially with relation to breeding, lactation and nutrition; of comparative pathology, particularly the various diseases of the udder of the cow, the abnormal conditions that affect milk secretion, and the infectious diseases of cattle and of man that may be transmitted by milk; of bacteriology, in regard to the pathogenic organisms and the saprophytes that occur in milk, their effects, their behavior under various conditions and especially at different temperatures; of the chemistry of milk and its adulterations and, besides these, there must be added

certain, important chapters from animal husbandry, dairy husbandry and dairy industry.

Until quite recently, milk inspection in the United States has been carried on by untrained men who have had little, if any, knowledge of the sources or nature of the contaminations of milk or of the means by which they must be avoided; their whole technical equipment has consisted in a few rule-of-thumb tests to detect gross adulterations. A large number of milk inspection services are still organized on this basis. In several cities, however, attention has been paid to microscopic and bacteriologic examinations of milk, and it has been shown that a very large proportion of the supply fails to meet even a moderate standard for cleanliness, thus revealing the need for measures at the seat of production and during transit to prevent injurious contaminations.

It is becoming increasingly manifest to sanitarians that more must be done to protect consumers from the unwholesome conditions and the diseases propagated and transmitted by milk and the broader men in dairy industry realize that milk must be made safe and be protected if it is to find and retain its proper place in the dietary of the people.

This makes a demand for a discussion of milk hygiene from the standpoint of the sanitary supervision of market milk—from the side of the man who is to do the practical work of protecting the milk supply—and it is this demand that Professor Jensen's book is planned to meet.

LEONARD PEARSON.

PART I.

INTRODUCTION.

Cow's milk has a peculiar place among our food stuffs in that it is not only an important and indispensable part of the daily dietary of most people, but it is being used more and more for the feeding of infants and, indeed, is often almost the exclusive food for children during the first years of life. It is, therefore, quite natural that at present when the science of hygiene is receiving so much attention—especially in relation to the large cities—that there should be a demand for a reliable supervision of market milk. It is true that the milk trade in cities has been subject to a certain inspection, but attention has been directed to only one side of the question, to the possibility of adulteration, and to provide that fat is not removed and that there is no alteration in the composition of the milk. From the standpoint of hygiene this is merely of secondary importance because it is in other ways that milk acquires dangerous properties and may, indeed, become the means of spreading virulent diseases.

A properly organized milk control of the present day can not, therefore, be restricted to determining that milk offered for sale is unadulterated. On the contrary, it must be its chief purpose to prevent milk possessing injurious properties from coming into the market and to prevent market milk from acquiring such properties during the time that it is being handled and stored. Since it is possible only by means of a thorough, tedious examination to determine whether a given

sample of milk is unwholesome, milk control can not be restricted to a simple inspection of the milk or to taking a sample for further examination. *To insure real safety, the inspection must be broadened to cover the health and feeding of the cattle, the cleanliness of the producing plant, the method of handling and caring for the milk and the condition of health of the people who come in contact with it.* Milk control is, for the reason stated, more difficult and more expensive than, for example, meat inspection, and this is undoubtedly one of the principal reasons why the control of milk production and the milk trade is so defective in most countries.

During recent years, a somewhat comprehensive control of the milk trade in its various relations has been carried out in a number of large cities, but a thoroughly satisfactory system does not exist and will be difficult to establish on account of its cost. In Denmark, a long step has been taken in the matter of milk control through the voluntary initiative of a single large company which, at a time when milk hygiene was receiving little attention, inaugurated a very comprehensive system of control, and thereby set an example that has been followed by other large companies, not only in Copenhagen but also in foreign countries. These companies have, in some respects, carried their control to a point far beyond that contemplated at the time by the public authorities.

Copenhagen is on the point of supplementing its health laws in relation to the milk trade within its limits.

As it is chiefly through the work of Veterinarians that meat inspection has gradually increased and is now conducted in a scientific manner, so, to a large extent, we have to thank the Veterinarians for the fact that the control of the production and sale of milk is grow-

ing steadily. Not only is important scientific work being carried on by them in several directions, which supplements the work of chemists and physicians, but the necessity for milk control is constantly being pointed out in meetings of veterinarians, in the International Veterinary Congresses and in the Congresses for Hygiene. A special journal is devoted to questions pertaining to milk hygiene, in conjunction with meat inspection, and separate courses in milk hygiene are given in many Veterinary Colleges.

What follows is essentially the substance of lectures given by the author in the Veterinary and Agricultural College of Copenhagen. On some points in the preparation of the book, the lecture notes have been expanded; for example, in citing the instances of disease resulting from milk possessing injurious properties. Since veterinarians are frequently consulted, by sanitary officers and by dairymen, in regard to the adulteration of milk, it is considered to be desirable to discuss rather thoroughly the composition of milk, the variations that occur under different conditions, and the adulterations. It is also considered to be appropriate to briefly treat upon the use of milk as food for infants.

Division of Subject

The subject matter of this book is divided into the following parts:

Milk and its composition.

Injurious properties that milk may possess.

Pasteurization and sterilization of milk.

The use of milk for infants.

In order to prevent the expansion of the book to unnecessary proportions, the hygiene of other dairy products as cheese and butter, and milk preparations as condensed milk, milk powder, etc., is not discussed.

PART II.

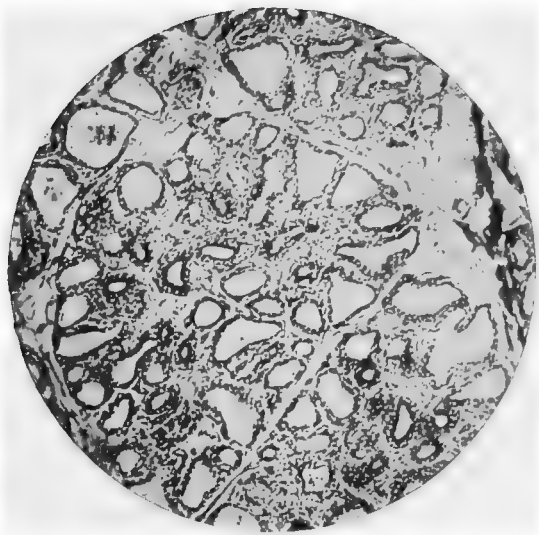
MILK AND ITS COMPOSITION.

I. THE MILK GLANDS AND MILK SECRETION.

The tissue of the milk glands is shown by macroscopic examination (Fig. 1) to be composed of small lobules separated by bands of connective tissue in which lie the larger blood vessels, the nerves and the excretory ducts and in which there is sometimes a considerable quantity of fat tissue. The gland tissue itself is composed of complexly branching glandular tubes which, during the period of lactation, are provided with numerous globular distensions, so that the type of the milk gland is intermediate between that of the alveolar and tubular types. The glandular pockets are provided with a *membrana propria* (Fig. 2) and are lined with epithelial cells. In young and farrow animals, the cells are thin and square or high and narrow, and resemble superficial epithelium. During the period of lactation these cells become large and tense. This epithelium is usually composed of but a single layer, although, in old cows, it is sometimes found to be composed of several layers.

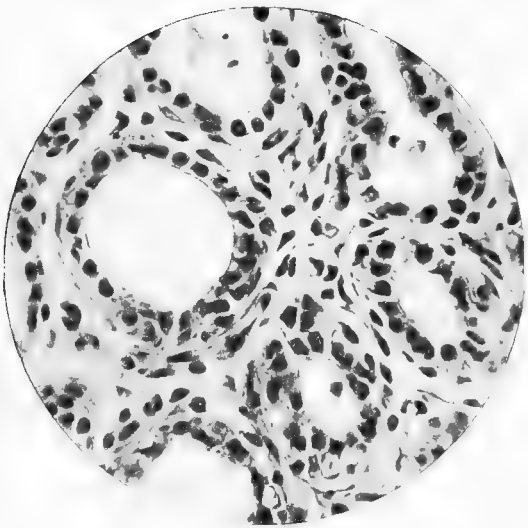
Toward the end of gestation, the secretory function of the udder begins with the production of colostrum or the so-called "beast milk." This is a thick, reddish or yellowish fluid with a taste more salty than that of normal milk, and under the microscope (Fig. 3) it is seen that it contains numerous free fat globules and a large number of round or mulberry shaped cells—the so-called colostrum bodies—that are filled with fat globules.

FIG. 1.



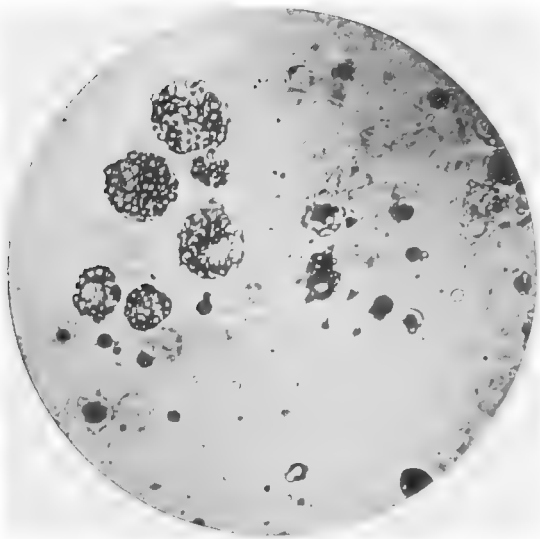
Section of udder tissue of a cow. Low magnification. One entire lobule is shown and parts of five others. Microphotograph.

FIG. 2.



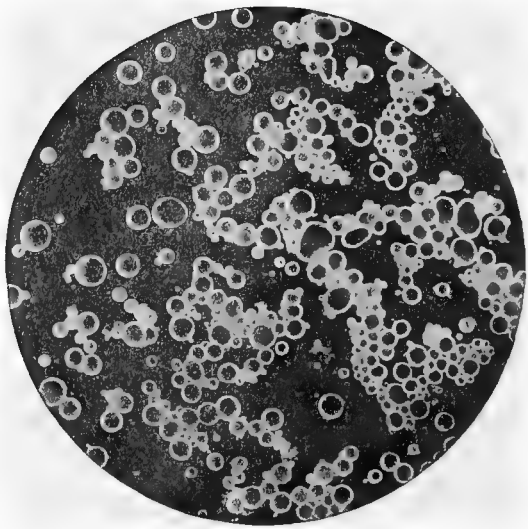
Section of the udder tissue of a cow. High magnification. Shows individual glandular pockets with their endothelial lining and the connective-tissue framework. Microphotograph.

FIG. 3.



Colostrum.—The udder secretion of a cow that has recently calved. Stained lightly with osmic acid, causing the fat globules to become dark. Shows several colostrum bodies and fat globules. Microphotograph.

FIG. 4.



Milk.- The fat globules are shown as light circles on a dark background. Micro-photograph.

Some cells are seen that have a distinct amœboid movement; these are leucocytes that have wandered through the epithelium into the glandular pockets and have taken up some globules of fat. Besides these, there are to be found some epithelial cells that have undergone more or less degeneration.

The chemical examination of colostrum shows its principal constituents to be: water, proteids (especially globulin and albumin, and also casein and nuclein compounds), sugar, fats and cholesterin, and, besides these, lecithin, various salts and other substances in smaller quantities. Colostrum differs from normal milk in its higher percentage of solids and especially in its higher content of globulin, albumin, nuclein compounds and lecithin. The chemical composition of colostrum differs slightly among animals of different species. In the course of a few days, the secretion of colostrum passes into milk secretion so that at the expiration of about one week, the secretion possesses the characteristic appearance and composition of milk.

The microscopic picture of milk is quite different from that described above. A very large number of fat droplets (milk globules, Fig. 4) of varying sizes, and a small number of more or less degenerated cells (colostrum bodies, gland cells) are distributed uniformly in a transparent fluid, the milk plasma.

It was formerly thought that milk secretion differed in important particulars from other secretions in that, it was considered, it occurred through partial destruction of the gland cells. It was supposed that during secretion the cells became longer and swollen, that the nucleus receded to the base of the cell while the part pointing toward the cavity of the alveolus became filled with numerous small fat globules. It was thought that after this "fatty degeneration" reached a certain

stage, there was a pouring out and solution of this part of the cell, that the fat globules were transformed into milk globules and the albuminous part of the cell protoplasm became part of the milk fluid and that the remaining portion of the cell, with the nucleus, was soon regenerated, whereupon a fatty degeneration again occurred in the regenerated portion of the cell. Recently, doubts have arisen as to whether, during the production of milk, there is, after all, a material disintegration of the cell protoplasm. Ottolenghis's investigations appear to show clearly that milk secretion is an active cell process precisely as other secretions are, and that it does not depend upon the destruction of the cell. The destruction of entire cells and their elimination appears to occur only to a limited degree, but the presence of karyokinetic figures shows that, here and there, in the gland, such a disintegration does occur with consequent reproduction.

The milk from animals of different species contains the same ingredients, namely: water, albuminoids (especially casein and albumin), milk sugar (lactose), fats and inorganic salts. In regard to quantitative composition, there are marked differences between the milks of animals of different species.

Among the ingredients of milk it is supposed that *casein* is the direct product of the gland tissue, *globulin* of the broken down parts of cells, while it is not known whether *albumin* originates at the same source or comes from the blood. Concerning the origin of *lactose,* there are different opinions. Some investigators suppose this material is formed in the liver from glycogen or related materials, while others think, and indeed with reason, that it is formed in the udder by synthetic building up of glucose and galactose. The latter cannot, as such, have been taken up with the food, but must have been

formed in the body by a breaking down of the galactins of the food. Others regard lactose as a product of certain proteids (glycoproteids). Milk *fat* is derived partly from the fat in the food, partly from the fat tissues of the animal; but these fats undergo a material transformation in the tissues of the udder, so that certain easily recognizable fats, even when taken up in quantity with the food, are either not visible at all in the milk or appear in very small quantity or are merely transitory. Doubtless, milk fat—just as fat tissue—may also be derived from the carbohydrates of the food. Among the other ingredients of milk, citric acid does not originate in the food, but results from metabolism.

Milk secretion, to a great degree, bears the impression of specific action of the cells which, however, may be influenced by external circumstances, but usually only temporarily. This is naturally of great importance for the young animal, which is nourished entirely or chiefly on its mother's milk, as frequent and sudden changes in the composition of the milk would be harmful, if not dangerous.

Milk secretion, it appears, may be checked through the influence of the central nervous system, but is regulated through the sympathetic nerve centres. In this connection, observations agree that certain irritant drugs (as pilocarpine) and other influences that decidedly affect the secretory function of other glands, influence milk secretion very little if at all; furthermore, section of the nerve trunks of the udder does not disturb secretion.

II. THE CONSTITUENTS OF MILK

As already mentioned, milk of different mammals consists essentially of the same materials, namely: water, protein, sugar, fats and inorganic matter; but

great differences are shown by quantitative analyses of the milk of the different species.

Water. The quantity of water usually amounts to 80 to 90 per cent. of the weight of the milk; under certain circumstances and with some animals it is even considerably less. With the whale, the quantity of water is scarcely 50 per cent.

Proteids. Of proteids, the three following are always found: *casein, lactalbumin and lactoglobulin.* A kind of albumose-like compound is sometimes found in insignificant quantity—the so-called animal gum—which is also found in certain tissue and in the saliva, and probably comes from the breaking down of glycoproteids (mucin, etc.). Moreover, other proteids are often described as normal constituents of milk (albumins, albumoses, meat acids, etc.), but it is safe to conclude that these do not occur in fresh milk, while such compounds are readily formed by bacteria and ferments and can be formed by chemical means.

Casein is a nucleo-albumin and, as such, it contains phosphorus. It is insoluble in water, but, by virtue of its property as an acid, it forms soluble salts with alkalies. There are two series of casein salts, basic and neutral; the solutions of the latter have a milky appearance. Casein is found dissolved in milk in the form of a neutral lime salt, which aids in giving to milk its white, opaque appearance. When boiled, a solution of casein is overcast with a thin membrane of coagulated casein; but a real coagulation, as it occurs in albumins and globulins, does not take place. When the fluid has reached a certain degree of acidity casein coagulates at 75° C. and the precipitated casein is not again soluble. After the addition of diluted mineral acids or of acetic acid, casein is precipitated as flakes or lumps, but undergoes no chemical change and is again easily soluble in

lime water and diluted alkalies. The separation depends only and solely upon the breaking down of the casein calcium compound. By rennet (chymosin, etc.) casein is precipitated as flakes (human milk and donkey milk), or as a firm gelatinous mass (*e.g.* cow's milk). The different modes of precipitation do not appear to come from the differences in the casein, but are due to the different salt content of the different kinds of milk. Under the influence of chymosin, casein is transformed into *paracasein*, which in its compound with lime is insoluble in water and, therefore, may be precipitated in this way.

The action of the rennet ferments is quite different from the precipitation of casein by acids. With the precipitation of paracasein, an albumose-like proteid remains in solution (whey proteid), so the action of the rennet ferment is to split the casein. By the growth of bacteria in milk, the casein is often thrown out of solution, either as a result of the formation of acids or by the chymosin-like effect of ferments produced by bacteria. Sometimes the separation occurs from the joint action of the ferments and the acids that are formed. In pepsin digestion, casein is dissolved with the formation of albumoses (caseoses) and paranuclein, which is rich in phosphorus. In the organism, paranuclein is dissolved by the pancreatic juice, is absorbed, and is excreted with the urine as phosphoric acid.

It has often been said that casein, as it is found in the milk of different animals, is not the same and, as evidence of this, reference has, incorrectly, been made to the different ways in which casein separates from milks acted upon by rennet. A more important indication, although the observation requires confirmation, is in the claim that in the pepsin digestion of human milk no paranuclein is formed. According to Hammarsten's thorough work, casein appears to show no chemical dif-

ference in different kinds of milk. The latest investigations concerning the powers of the organism to form specific anti-albumins (precipitins) following the injection of albumin solutions, prove, however, that the casein of different species of animals has certain differences, even though these are so slight that they cannot be detected chemically.

The *lactalbumin* is very similar to the albumin of the blood, but it appears to differ from this in some particulars. It coagulates at about 70° C., and, like all other albumins, it is not precipitated in a neutral solution of sodium chloride and magnesium sulphate, but it is precipitated in a saturated solution of ammonium sulphate.

The *lactoglobulin* occurs in milk in very small quantity, merely in traces, while colostrum is comparatively rich in this substance. It coagulates at 75° C.; it is precipitated in the same way as serum globulin and, like serum globulin, is insoluble in water, but is soluble to some extent in weak salt solution.

Carbohydrates. Of the carbohydrates, lactose, or milk sugar, occurs as a constant constituent in the milk of the cow and of most other mammals. Some investigators claim that in colostrum there is a monohexose, which is probably glucose, and it is not unlikely that in the milk of certain animals other kinds of sugar appear; for example, it is cited that a peculiar kind of sugar, tewficose, is found in considerable quantity in the milk of the Egyptian buffalo.

Lactose ($C_{12}H_{22}O_{11} + H_2O$) is a disaccharid which is split by hydrolysis (*e.g.* by means of heating with dilute acids, action of ferments) into glucose (grape sugar) and galactose as follows:

$$\underset{\text{Lactose}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Galactose}}{C_6H_{12}O_6}$$

Lactose has been found only in milk and must be formed in the organism; but this formation, as has already been stated, is not yet thoroughly understood. Commercial lactose is derived from whey as hard rhombic crystals which have a slightly sweet taste and are soluble in six parts of cold water. By the action of micro-organisms, lactose may ferment in different ways. Certain yeasts and bacteria cause an alcoholic fermentation, while other bacteria split lactose, forming lactic acid (causing "souring" of milk) and several other substances as by-products (CO_2, H, formic acid, butyric acid, etc.); still other bacteria form as their chief product, butylalcohol, succinic acid or acetic acid. Certain moulds are able to form oxalic acid from lactose by oxidation. Lactose, like glucose, reduces Fehling's solution when heated.

Fats are found in the milk as small droplets or globules, which accumulate upon standing into a layer of cream, and which are easily separated from the other constituents of milk by means of centrifugal force. Upon shaking milk or cream, the globules of fat gradually coalesce into larger drops and lumps (butter). It was formerly thought that the fat globules were surrounded by a membrane, but now it is generally believed that it is not so. However, under the microscope one can see a border on certain individual fat globules, which is to be regarded as a remainder of broken-down cell protoplasm.

Milk fat consists of a mixture of different fats, the principal of which are olein, palmitin and stearin, which are the neutral triglycerides of the corresponding fatty acids. Besides these are found the triglycerides of myristic acid and of butyric and capronic acids (the last two volatile) and also traces of triglyceride of other fatty acids (caprylic, caprinic, laurinic and arach-

inic). The composition of the fat is subject to numerous variations and these are not alone racial peculiarities, for individual traits, the composition of the food and external conditions of life not infrequently influence it.

Other Substances. Milk contains other substances in very slight quantities: urea, kreatin, kreatinin, lecithin, cholesterin and citric acid. It is not yet known if these appear in the milk of all animals or whether some of the substances are characteristic of certain animals only.

Besides these substances, milk contains some *inorganic salts* in solution, which remain after evaporating and burning the milk. The ash consists of lime, potash, sodium, small quantities of magnesia and traces of oxide of iron in combination with phosphoric acid, chlorine and sulphuric acid. The small surplus of basic substances in the ash were in combination with citric acid and, perhaps, with other organic acids. Phosphoric acid and lime exist partly as soluble compounds, partly in combination with casein. A little di- and tri-calcium phosphate are held in solution by the action of the casein and are therefore precipitated with it. The milk of different species and sometimes of different individuals, shows a quantitative difference in the ash.

According to recent investigations, milk, at least cow's milk, always contains a ferment, the so-called *galactase* (Babcock, Russell), which is capable of slowly peptonizing protein. The significance of this ferment and its composition are wholly unknown to us; possibly it comes from the breaking down of the leucocyte (Barthel).

Certain *gases* occur in the free state in milk. Investigations on this subject have given varying results, in that some investigators have found distinct quantities of oxygen in milk just drawn, others have

detected only a trace, or none at all; moreover, milk always contains considerable carbonic acid and a slight quantity of nitrogen. Upon standing, this relation changes, for carbonic acid escapes and oxygen is absorbed.[1]

III. THE COMPOSITION OF MILK OF DIFFERENT SPECIES OF ANIMALS

It has been stated that the milks of different species of animals consist of essentially the same materials, but that in their quantitative composition they show quite a little difference. As will be considered in detail later, there are great variations with individual animals and, therefore, the figures given are to be regarded as averages and they are to be accepted with some reserve, for not all are the result of a sufficiently great number of analyses; still, they give quite a good picture of the striking peculiarities of the different kinds of milk.

Cow's milk is white, opaque, has a slightly sweetish taste and a very slight odor. It shows amphoteric reaction to litmus paper, *e.g.*, it colors red litmus paper bluish and blue reddish. To other indicators, milk sometimes shows itself to be acid, sometimes alkaline. According to Courant, it can be demonstrated that 100 c.c. of fresh cow's milk shows the same amount of alkalinity toward blue litmus as 41 c.c. of a one-tenth normal solution of sodium hydrate and the amount of acidity, as measured by phenolphthalein, is equivalent to that of 19.5 c.c. of a one-tenth normal solution of sulphuric acid. However, milk does not always react the same, it changes especially during the course of the period of lactation. The casein of cow's milk is precipitated

[1] Richmond says: "As the milk is kept the amount of oxygen decreases and that of carbon dioxide increases; this is probably due to aërobic microörganisms, which absorb the oxygen and give out carbon dioxide." [L. P.]

by chymosin as a firm, jelly-like mass. The butter-fat contains a yellow coloring stuff.

The qualitative composition of cow's milk averages as follows (Fleischmann): water, 87.75 per cent.; fat, 3.4 per cent.; casein, 3.0 per cent.; albumen, 0.5 per cent.; lactose, 4.6 per cent.; salt, 0.75 per cent.[2] Lactoglobulin and lecithin are found only in very slight quantity; citric acid is found in quantities of from 0.1 to 0.15 per cent. Analysis of the ash shows its constituents to be present in the following proportions:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	Cl	SO_3
25.81	11.78	19.71	2.77	0.13	23.11	16.15	4.07%

But there may be a considerable amount of variation, especially in the potash, magnesia, chlorine and sulphuric acid, since the consumption of certain salts in great quantity cause changes in the composition of the ash. The quantitative composition of cow's milk varies greatly among the different breeds and individuals, and at different stages of the period of lactation (see the next section).

Zebu's Milk coincides almost wholly in its properties

---

[2] Richmond gives the following average composition of milk, based on the analysis of 200,000 samples taken from the supply of a dairy company in London:

	Per cent.		Per cent.
Water	87.10	Casein	3.00
Fat	3.90	Albumin	0.40
Milk sugar	4.75	Ash	0.75

A very large proportion of the cows producing milk for the London market are of the Shorthorn breed. [L. P.]

The following is taken to represent "milk of good average quality" in Massachusetts:

	Per cent.		Per cent.
Water	87.00	Casein	3.00
Fat	4.00	Albumin	0.50
Milk sugar	4.80	Ash	0.70

(Bulletin 110, Hatch Experiment Station.) [L. P.]

and quantitative composition with ordinary cow's milk.

Buffalo's milk, which possesses a slight, pleasing odor and taste, is richer in solids than cow's milk, since the quantity of fat amounts to about 8 per cent., the proteids to fully 4 per cent. and lactose to 4.75 to 5.2 per cent.

Goat's milk is pure white, without especially pronounced odor or taste. If, however, the milking takes place in the stable in which male goats are kept, the milk very easily absorbs the same characteristic unpleasant odor. The chemical composition of goat's milk is similar to that of cow's milk; frequently, though, the fat content is a little greater. The butter-fat is white.

Sheep's milk is a whitish yellow, rather thick and possesses a peculiar, somewhat unpleasant taste and odor. It differs from cow's milk and goat's milk in its high fat and casein content, averaging about 9.0 per cent. and 6.3 per cent. respectively. Moreover, the fat content is very variable, for with some breeds it amounts to 11 to 12 per cent. and even more, while with others it amounts to only 2 to 3 per cent. The examination of milk of 2,700 sheep (Sartori) showed an average specific gravity 1.0374 and the following composition: water 78.70 per cent., fat 8.94 per cent., proteids 6.3 per cent., lactose 5.06 per cent., ash 1.015 per cent. The average analyses for 250 other sheep (Fleischmann) were as follows: water 75.54 per cent., fat 11.90 per cent., casein 5.83 per cent., albumin 1.33 per cent., lactose 3.43 per cent., ash 1.05 per cent.

Mare's milk is usually distinctly alkaline to litmus, but may be neutral. It is white or bluish in color and has a somewhat pronounced sweet taste due to its high lactose content (about 6.6 per cent.). The proportions of fat and proteids are conspicuously small; as in the averages of 15 analyses (Veith) only 1.09 per cent. fat and 1.89 per cent. proteids (of which about a third was

albumin) were present. The inorganic salts (ash) are present only in small quantity (0.31 per cent.).

Ass's milk is essentially the same as that of the mare; it has in common with the latter the low fat and proteid content and the large quantity of lactose. The composition is given somewhat differently by different writers. Ellenberger, Seeliger and Klimmer found as the average of a large number of analyses: water 91.20 per cent., fat 1.10 per cent., proteids 1.50 per cent., lactose 6.0 per cent., ash 0.40 per cent. The reaction is decidedly alkaline to litmus. On account of the small proportion of salts, the casein is precipitated by rennet as a flocculent, disunited mass. Milk of the ass more nearly resembles human milk than does that of any other animal, and in Southwestern Europe, for the most part, milk of the ass is the principal substitute used for the nourishment of infants.

Woman's milk, which reacts amphoterically, is regularly somewhat richer in lactose than cow's milk, but it contains less proteids and also less ash, especially phosphoric acid and lime. While the lactalbumin in cow's milk constitutes but one-fifth to one-sixth of the protein, in human milk during the first part of the period of lactation, albumin and casein are present in almost equal quantities; later, casein increases a little. The average percentage of fat is approximately the same as in cow's milk, but it varies considerably, from 1.3 per cent. to 7.8 per cent. Human milk is richer in lecithin, but poorer in citric acid (about 0.5 per thousand) than cow's milk. According to E. Gottlieb the following numbers represent the average composition of 104 samples: water 87.92 per cent., fat 3.43 per cent., casein 0.58 per cent., albumin 0.52 per cent., lactose 7.12 per cent., ash (salts), 0.25 per cent. Woman's milk is subject to individual variations to a great degree, as is shown by

the table below, which is taken from Gottlieb's analyses:

	Water.	Fat.	Casein.	Albumin.	Lactose.	Ash.
"Normal" milk.....	87.52	3.38	0.78	0.39	7.51	0.27
Rich milk.....	85.24	5.91	0.87	0.36	7.24	0.24
Poor milk	89.65	1.66	0.57	0.27	7.47	0.23

Each number represents the average of four analyses taken several days apart. Each sample came from a young woman who had been confined a few months before.

It has often been said that casein in human milk differs chemically from that of cow's milk; but, as stated above, according to the investigations of recent years, there is good reason to believe that this is not the case. (Hammersten, Cohnheim.)

Sow's milk is thick, slimy and of alkaline reaction. In chemical composition it is very variable, especially so in regard to the fat content which varies between 1.0 per cent. to more than 12.0 per cent. In some of the analyses reported, it appears that a distinction has not been made in relation to the proportion of fat of the milk that was drawn first and that drawn last, but since the other ingredients of the milk were found in different proportions, the variation can not be doubted. The quantity of protein averages about 6.0 per cent. but may vary from 5.7 to 15.5 per cent. The quantity of lactose varies from 2.0 per cent. to 3.8 per cent., the ash from 0.77 per cent. to 1.18 per cent. On the whole, it may be said that sow's milk is quite concentrated.

Bitch's milk is also quite variable in its composition. The fat content varies between 4.0 per cent. and 12.0 per cent., the proportion of casein between about 3.5 per cent. and 6.0 per cent., albumin is present in about the same quantity as casein, there is about 2.0 per cent. to 3.0 per cent. of lactose and about 1.0 per cent. of ash.

The milk of the cat has not received much study. According to some analyses that have been made (by Cornaille), it is of about the

following composition: fat 3.33 per cent., casein 3.12 per cent., albumin 5.96 per cent., lactose about 4.9 per cent., and ash 0.59 per cent.

The *rabbit* and the *reindeer* give milk particularly rich in fat and especially concentrated, but poor in lactose. The milk of the *elephant* shows very great fat and sugar content and comparatively little protein.

A milk differing greatly from the usual is that of the *whale*. It contains only from 41.0 per cent. to 48.0 per cent. of water, and fat in the enormous proportion of 43.0 per cent. to 45.0 per cent. There is 7.5 per cent. to 11.0 per cent. of protein and only about 1.3 per cent. of sugar.

The table below shows the average analysis of human milk and of the other kinds of milk used as food for man:

	Cow.	Goat.	Sheep.	Ass.	Mare.	Woman.
Water	87.75	87.30	75.54	91.20	90.00	87.92
Casein	3.00	3.00	5.83	0.90	1.26	0.58
Albumin	0.50	0.50	1.33	0.60	0.63	0.52
Fat	3.40	3.90	11.90	1.10	1.09	3.43
Lactose	4.60	4.40	3.43	6.00	6.65	7.12
Salts	0.75	0.80	1.05	0.40	0.31	0.25

IV. VARIATIONS IN THE COMPOSITION OF COW'S MILK

It has already been stated that the composition of the milk of the cow, as well as that of other animals, may vary more or less. So far as the variations of cow's milk are concerned, they are not very great, still they are of sufficient importance to make it necessary to take them into consideration in connection with its production, sale and control. The above figures give approximately the average composition of cow's milk and, of course, correspond with the composition of market milk, which consists of a mixture of milk of several or many cows.[3] The separate constituents vary in quantity

[3] These are Danish figures; in America the average for market milk is higher. [L. P.]

in different degrees, the fat content varying the most, the albumin, lactose and ash ingredients less. In "rich" milk the fat content often considerably exceeds the average, while the proportions of protein and lactose are never much higher than the averages given. On the other hand, with thin, poor milk the fat per cent. may fall far below the average, while the proportions of protein and lactose depart but slightly from the average. These variations are not due merely to the elimination of water from the milk, that is, to a simple concentration, but rather to a qualitative variation in the activities of the gland cells.

Just as is the case with other glands, the milk glands may be stimulated to greater activity, so that the quantity of secretion increases, but its chemical composition is not disturbed, or only slightly, or temporarily, until the gland tissue has accustomed itself to the new condition. Drinking a large quantity of water causes no increase in milk secretion; the gland cells do not secrete more water than the quantity required to maintain the proper proportion to the milk solids. Food containing much water has no permanent effect upon the composition and the quantity of the milk. The influence of such materials as pilocarpine and atropine, which increase or reduce other secretions in a great degree, have no direct, or only a very slight influence on the milk secretion, apparently because this is controlled by the sympathetic nerve centres. The various conditions that have, or are believed to have, an influence upon the chemical composition, and especially upon the fat content of milk, are considered in the following paragraphs.

1. **Breed peculiarities.** Cows of different breeds give milk of somewhat different composition. In general, it is believed that breeds from the highlands and

mountainous regions give a richer milk, while breeds from the lowlands yield milk poorer in fat. There are, it is true, exceptions to this rule, *e.g.,* the Allgauer and the brown Swiss cattle give rather a poor milk, while the Devons and the Normandy cattle give milk rich in fat. As an example of breeds that give milk especially rich in fat we may mention the Jerseys and the Guernseys, whose milk contains an average of 4.5 per cent. to 5.5 per cent. fat, also the Harz cattle, whose milk is reported to contain an average of 5.8 per cent. fat. On the other hand, milk of the Swiss cows has only 3.0 per cent. fat, that of the Angler and Breitenburger and other breeds only about 3.13 per cent. to 3.15 per cent. fat. The average of the Danish breeds can hardly be placed higher, being about 3.2 per cent. to 3.4 per cent. fat.

2. **Individual peculiarities.** The figures given above are averages only. The milk of different individuals varies more or less so that in the same breed there are individuals that give milk rich in fat, and also those whose milk has a percentage of fat below the average of the breed in question. The production of rich milk is, therefore, a distinctly individual property that is due to the physiological peculiarities of the gland cells of the animal, and which appears, to a great degree, to be hereditary. Among cows of the same breed may be found some whose milk contains 4.0 per cent. or more of fat and, on the other hand, there are many that give milk containing only about 2.5 per cent. fat; indeed, not infrequently the percentage of fat is still lower, and from Germany there are records of cows that give milk containing not more than 1.5 per cent. of fat. Such cows are frequently and in large numbers excluded from the best herds, so when herds are made up of purchased cows, the mixed milk from such cattle often contains but

little fat and may not exceed 2.25 per cent. to 2.75 per cent.[4]

While it is scarcely possible, as will be discussed later, to influence the composition of milk materially or permanently by alterations in the quantity and composition of the food, still it may not be entirely impossible to influence the young animal by skilful or by appropriate feeding in such a way as to encourage it later to produce milk rich in fat. But thoroughly reliable data on this point are not available.

3. **The age of the cow.** Although the quantity of milk varies according to the age of the cow, so that it is usually greatest during the third to the fifth lactation periods, the chemical composition appears to remain almost unchanged from year to year (Hittcher); yet it is apparent that fats as well as other ingredients decrease with great age.

4. **The stage of the lactation period.** The colostrum secretion is not especially important. The true milk secretion very quickly attains a considerable volume, but falls off gradually after a longer or shorter time, until the secretion ceases altogether or is insignificant towards the end of the period of gestation. Some cows, however, continue to milk very well up to calving and to the new period of lactation. It was emphasized above that colostrum differs essentially, both morphologically and chemically, from normal milk. Furthermore, the composition of milk during the first part of the lactation period differs from that secreted toward the close.

a. *Colostrum.* The first colostrum is whitish, yellowish, or even reddish to brownish; it is slimy and has a

[4] It should be borne in mind that the cattle here referred to are of heavy milking lowland breeds not represented in America. [L. P.]

specific gravity of 1.040 to 1.080. Its microscopic appearance has been described before and, in part, its chemical composition. Gradually, the appearance and the composition of the secretion changes until, in the course of about a week, it becomes pure milk. This gradual development is illustrated by the following analysis given by Eugling:

	Number of hours after calving.					Normal milk.
	Immediately.	10	24	48	72	
Water	73.17	78.77	80.63	85.81	86.64	87.75
Casein	2.65	4.28	4.50	3.25	3.33	3.00
Albumin } Globulin }	16.56	9.32	6.25	2.31	1.03	0.50
Extractives	3.54	4.66	4.75	4.21	4.08	3.40
Sugar	3.00	1.42	2.85	3.46	4.10	4.60
Ash	1.18	1.55	1.02	0.96	0.82	0.75

These figures show that the chief difference in the composition of milk and colostrum consists in the greater albumin and globulin content of the latter, which arises partly from the presence of numerous colostrum bodies, in consequence of the presence of which colostrum coagulates when heated. Another important difference is the low sugar content of colostrum; according to Tereg the sugar of colostrum is not lactose, but is grape sugar, or perhaps a mixture of this and galactose. Of the substances that are extracted with the fat, about 13.8 per cent. consists of cholesterin and 8.0 per cent. of lecithin.

Among other peculiarities shown by colostrum of the cow may be mentioned its acid reaction and the fact that after the addition of rennet it does not coagulate at all, or only very slowly.

b. *Milk.* Shortly after calving, while the secretion

is abundant, the milk is generally a little less rich in solids and especially in fat than it is later when the secretion begins to fall off; with some cows the difference is not very great, but with others it is considerable. In the last month the secretion falls off rapidly and often ceases entirely; at the same time the proportion of solids usually increases and this is especially the case in relation to fat. The milk gradually acquires a decided alkaline reaction to litmus paper and not infrequently develops a salty taste. The changes in composition are shown in the following table, which gives the results of analyses, made by Fleischmann, of the milk of one cow which calved January 28th.

With this cow, the percentage of fat during the period of lactation rose from 3.033 to 8.300; but this significant increase occurred almost entirely in the last month when the cow had become an old milker. At the same time the quantity of albumin, lactose and salt (*i.e.*, solids not fat) increased only from 8.14 per cent. to 9.00 per cent.

The chemical composition of milk of some cows does not change noticeably during the whole period of lactation, and the percentage of fat as well as the other solids may even fall off a little at the end of the lactation period. Fleischmann gives a table showing analyses of the milk of such a cow for the whole lactation period: the daily quantity of milk in April was 19.84 kg., on the 31st of January following it was 3.6 kg. The fat percentage, which had varied between 2.56 and 2.97, fell in January to 2.42, 2.60, 2.32, and 2.48 upon different analyses. The percentage of solids not fat also fell a little.

5. **The time and method of milking.** It is commonly believed that there is always a slight difference between the chemical composition of the morning and the even-

ing milk in that the latter is richer in fat than the former. Numerous investigations have given very variable results that may be explained by the short duration of the test, by the daily variations of the composition of the milk, etc. Some larger experiments relating to

LACTATION PERIOD

	Daily quantity of milk. Kg.	Specific gravity.	Fat. Per cent.	Solids not fat. Per cent.	Fat content of the total solids. Per cent.
April	11.55	1.0291	3.033	8.140	27.15
May	11.95	1.0290	3.264	8.166	28.56
June	10.45	1.0287	3.405	8.113	29.56
July	8.82	1.0283	3.458	8.027	30.11
August	9.66	1.0287	3.586	8.149	30.57
September	9.07	1.0289	3.650	8.230	30.72
October	7.67	1.0292	3.434	8.247	29.39
November	6.63	1.0299	3.823	8.501	31.01
December	5.11	1.0300	4.267	8.616	33.11
January 2	3.0	1.0302	5.050	8.823	36.40
January 3	2.7	1.0300	5.400	8.843	37.91
January 4	2.8	1.0299	4.720	8.680	35.22
January 6	2.3	1.0307	5.470	9.032	37.71
January 7	2.4	1.0299	5.440	8.824	38.14
January 8	2.3	1.0304	5.250	8.911	37.07
January 9	2.3	1.0310	5.200	9.054	36.48
January 10	2.1	1.0308	5.090	8.980	36.17
January 11	2.2	1.0308	5.100	8.982	36.22
January 14	1.9	1.0277	6.900	8.565	44.60
January 16	1.3	1.0301	8.300	9.446	46.77
January 18	1.4	1.0288	7.480	8.958	45.50

many animals and extending over a long period, have proven that the morning milk does not differ from the evening milk in fat content when the period between the milkings is equally great and the feed, the amount of drinking water taken, etc., are the same. But in practice this is not the case, because usually a small difference exists, so that where there is a larger quantity

of milk there is a smaller percentage of fat. Fleischmann found by continuous investigations of one herd of 120 to 130 cows during one year, that on the average for the whole year the morning milk contained a little more fat than the evening milk (3.260 per cent. against 3.183 per cent.), while the quantity of morning milk was a little less than that of the evening milk (4.143 kg. against 4.616 kg.).

There is a slight difference dependent upon the seasons; it has been shown that in the summer the morning milk contains a slight excess of fat while in the winter the evening milk is the richer. It follows that since the quality of milk is influenced by external influences, there can be no general rule to define the difference between morning and evening milk but, usually, if no other conditions arise, this difference is comparatively small.

It is commonly believed that three milkings a day cause not only the production of a greater quantity of milk, but also a somewhat greater percentage of fat, but it can scarcely be said that there is definite proof of an increase in the percentage of fat.

If the milking is done by a strange or inexperienced person, the flow is diminished. This also influences the quality of the milk. The first and the last milk drawn differ greatly in fat content. It is supposed that the fat globules adhere firmly to the walls of the ducts, as a layer of cream, and are freed from these only with difficulty. The following figures show the results of analyses by de Vriezes, who found in the first streams 1.2 per cent. fat; after drawing about one-quarter the quantity of milk, 2.1 per cent. fat; after drawing about one-half the quantity of milk, 3.6 per cent. fat; after drawing about three-quarters the quantity of milk, 5.2 per cent. fat; in the last milk, 7.1 per cent. fat; in the very last drops of milk drawn, 10.0 per cent. fat.

Therefore, by milking a single cow, one can obtain milk of the greatest variety of fat content, which must be considered when samples are taken from individual animals for the purpose of examination. According to Hittcher's investigations, the situation seems, singularly enough, to be wholly changed if the calf is permitted to suck the cow; the milk that remains is not rich, but is much poorer in fat.

Number of the cow.	Fats. Per cent.		Solids not fat. Per cent.	
	Minimum.	Maximum.	Minimum.	Maximum.
1	2.621	4.698	7.859	8.771
2	2.160	3.404	7.293	8.707
3	....	....	....	....
4	2.163	3.965	7.702	8.743
5	2.543	3.900	7.636	8.577
6	2.096	3.446	7.753	8.893
7	2.257	3.837	7.974	8.914
8	2.690	4.117	7.943	8.897
9	2.566	4.709	8.197	10.050
10	2.464	6.000	7.728	8.939
11	2.741	4.649	8.305	9.371
12	2.509	5.505	8.582	9.550
13	2.645	4.724	8.389	9.623
14	2.097	4.173	8.394	9.131
15	2.437	4.234	8.031	9.046
16	2.326	4.637	8.040	9.363
17	....	....	....	....
18	2.537	4.390	8.098	9.170

The opinion expressed in recent years, that by a special method of milking the average fat percentage of milk of individual cows may be raised, is incorrect.

6. **Daily variations.** Daily examinations of milk of individual cows show that not only the quantity of milk undergoes change from day to day, but, at the same

time, strange to say, the chemical composition of the milk is subjected to daily variations that may reach considerable extent. Knowledge of this is naturally of the greatest importance in the detection of milk adulteration. The table on page 34 is given by Fleischmann to show the minimum and maximum fat percentages in the milk of a series of cows examined daily during an entire period of lactation.

As is shown, the percentages of fat differ considerably even in milk from the same cow; one cow, number 12 in the table, produced milk differing in fat content as much as 100 per cent., that is, from 2.509 to 5.505 per cent.

Cow No. I.	Cow No. V.	Cow No. VII.	Cow No. VIII.
3.214	3.040	2.566	3.551
2.869	2.825	....	3.592
2.859	3.322	3.080	3.244
2.862	....	3.314	2.932
....	3.043	2.822	2.790
3.294	3.790	2.329	3.047
3.070	2.996	2.308	....
2.847	3.369	2.616	2.816
3.685	3.272	3.334	3.199
3.749	3.189	3.381	3.732
4.031	3.267	3.402	3.620
3.927	3.068	3.316	3.522
3.792	3.795	3.344	3.492
3.844	3.470	2.970	3.633

The variations are not always gradual, but occur spasmodically, as is evident from the figures above, taken from Fleischmann's work on milk. The numbers in the perpendicular columns give the percentage of fat for successive days; the figures above the dividing line date from the beginning of the lactation period of the cows, while below the line the figures given refer to

the end of the milking period. The examples are chosen in order to make plain the daily variations with the individual animals.

One may find even greater variations by examining the morning and evening milk. As examples, some results are given from the daily examinations of milk from the above mentioned cows number I and number V, the figures referring alternately to the morning and the evening milk on successive days:

	Cow No. I.	Cow No. V.
Morning	3.375	3.180
Evening	2.640	2.940
Morning	3.240	2.710
Evening	3.995	2.900
Morning	—	2.750
Evening	—	3.700
Morning	3.800	—
Evening	3.250	—
Morning	4.100	2.360
Evening	3.815	3.560
Morning	4.145	4.530
Evening	3.485	3.180
Morning	4.085	3.220
Evening	2.785	2.800
Morning	—	3.690
Evening	3.590	3.100

The changes in the quantity of solids not fat (protein, lactose and salts), as is apparent from the above tables, are much less than those of the fat, and especially do lactose and salts vary but little.

The reasons for these daily variations in the quantitative composition of milk are not yet wholly understood, but are to be sought in everything that in any way has an unfavorable influence on the animal; changes of food (see below) or of the times of feeding and drinking, changing to a strange place, restlessness in the stable, storms, œstrum, changes at milking, etc. Very often no definite reason can be discovered and it appears that

such variations may take place without external causes. With cows that have suckled their calves, after separation from the calf, there is usually a very noticeable decrease of fat in the milk, which is sometimes made good by a subsequent considerable temporary increase.

7. **The influence of food.** It is an old and, in some places, still commonly accepted opinion that the composition and the quantity of the food have an important influence on the composition of the milk and more especially on its fat content. Palm and cocoanut meal and several other food stuffs, are said to encourage the production of rich milk, while, on the other hand, distillery slops, for example, are said to cause the production of poor milk. During recent years, numerous investigations undertaken abroad as well as in the experimental laboratory in Copenhagen, seem to have proven that it is not possible by changes of food to bring about a noticeable permanent effect upon the composition of the milk. The activity of the udder cells, as is shown from the daily variation in the composition of milk, is easily thrown out of equilibrium, but such a condition is only temporary. With changes of feeding, this condition appears quite plainly, nearly every change very quickly causing a variation in the composition of the milk, especially the fat percentage, so that sometimes this rises, sometimes, *e.g.*, when distillery slops and similar moist foods are fed, it falls off more or less. But this variation always seems to be merely temporary; in the course of a day or so, sometimes, however, not until the end of a couple of weeks, the average percentage returns. This is the case even when food of only one kind, as distillery slop and, indeed, when food especially rich in fat, is fed; in these cases, also, the change in percentage will be only temporary (Henriques and C. Hansen).

To be sure, there are many reports in print of other results, but upon examination these are found to extend over so short a period that the temporary changes had not yet disappeared, or they refer to investigations with different cows whose milk was not sufficiently examined, or to cows that did not receive the same food in the beginning of the experiment, or, finally, sufficient allowance was not made for the daily variations and for those that occur at different stages of the lactation period.

The temporary changes in the composition of milk which occur after a change in the food, may be considerable, but here, too, the question of individual peculiarities enters, so that the changes shown by two cows under the same conditions may differ materially.

It is of an old belief, that the change from dry food to green causes an increase in the fat content of the milk. The investigations in the Danish experimental laboratory have proven this; they show that the fat percentage under these conditions may increase 0.5 per cent., with some cows it increased even 1.0 per cent., but this increase lasted only a few weeks. Also, when changing the ration to include some of the oil cakes, a similar increase in the percentage of fat has been observed, but seldom more than about 0.5 per cent. On the other hand, as stated before, there are observations of temporary falling of the fat from 0.25 per cent. to 0.5 per cent. when a change of food is made to distillery slops or similar rations.

It is, then, possible to show that the udder reacts rather characteristically to certain changes in the ration and especially to some food stuffs; but this reaction is lost when the cow has become accustomed to the new food. Under such conditions, simultaneously with the increase of the fat percentage there frequently occurs a

decrease in the quantity of milk, while, on the other hand, a lessening of the percentage of fat is often accompanied by an increase in the volume of the milk.

Although recent experiments have thrown much light upon the influence of food on the milk secretion, yet there is need for further information on many points. For instance, it is not known with certainty if it is possible by long continued, particularly unfavorable, one-sided composition of food, to produce lasting changes in the fat content of milk and in the solids not fat.

Lactose occurs in milk in but one form and the character of proteids is not affected by the nature of the foods. On the other hand, the milk fats vary, sometimes there is more and sometimes less olein, which affects the consistency of the butterfat, and the percentages of volatile fatty acids may vary considerably. It has often been said that the fats taken with the food do not pass unchanged into the milk. Only when a great quantity of food, rich in a kind of fat that can be distinguished chemically, is fed, is it possible to find small quantities of that fat in the butterfat of the milk.

But little is known positively concerning the causes of the variations in the composition of the butterfat and especially concerning the influence of the food upon it. The milk fat may originate in the fatty tissue of the animal, from the fat stuffs taken with the food and, apparently, also, directly from the carbohydrates consumed. There are a number of other conditions, as the composition of the ration, excessive feeding with fatty foods, starvation, etc., that have some influence in this direction but, as they are of no sanitary importance, it is unnecessary to discuss them here in detail.

It is generally believed that odors and tastes pass from the food that is consumed into the milk. The

milk of the Alpine cows is noted for its aromatic taste. Feeding with beet leaves, turnips, malt sprouts, etc., is supposed to be the cause of the taste and odor of beets or a burnt taste and odor in the milk. We do not yet know how much influence is to be attributed to the food. In some cases, the offensive odor and taste is undoubtedly due to the activity of bacteria in the milk—indeed, it is doubtful if the " beet taste " and the " burnt taste " ever come from the food (see below). Peculiarities of breed may possibly be the cause of the aromatic milk of the Alpine cows. On the whole, it is highly probable that the food has some influence on the taste and odor of the milk [this is unquestionable in the case of garlic,] *but by no means all of the substances in milk that have special odors and tastes are secreted with the milk.*

The ash ingredients of milk are not generally influenced to a great extent by the amount of salts taken with the food; even a considerable iron or phosphoric acid content of the food causes no direct increase of these materials in the milk; still, certain sulphates, as Glauber's salt, given in large quantities are excreted in small quantity with the milk, and consequently cause an increase in sulphuric acid in the ash.

While it is true that feeding influences the composition of milk only to a slight degree, it is nevertheless true that the quantity of milk is dependent to a very great degree on the amount and composition of the food.

8. **The significance of sexual conditions.** The occurrence of œstrum and pathological conditions of the generative organs cause a decrease in the milk secretion; therefore it has been assumed that these conditions may also cause changes in the chemical composition of the secretion, yet this does not always appear to be the case.

a. *Œstrum* has a very different effect on the milk secretion of individual cows. Kühn found no effect, but von Kleuze found such a great albumin content that the milk could not be boiled, and Schaffer established a remarkably high fat content. On the other hand, Fleischmann found only 0.714 per cent. fat in the evening milk of a cow that had come in heat in the course of the day, though the morning milk contained 3.56 per cent. fat. On the whole, it may be said that normal œstrum often induces a passing disturbance of the normal secretory activity of the udder.

b. *Nymphomania,* which has no slight influence on the nature of the meat, and reduces the milk secretion considerably, probably influences the nature of the milk also. Only a single analysis of such milk is given by Schaffer; the quantity of fat and lactose had not changed, but the quantity of protein was remarkably high, namely, 5.72 per cent.

c. *Ovariotomy.* As is known, it is frequently claimed that spaying performed on healthy cows during the first months of the lactation period causes a considerable lengthening of this period, an increased daily secretion, and greater fat content of the milk. However, it can hardly be said that this is sufficiently established; and especially, it is not to be considered as proven that ovariotomy is able to raise the fat content; in fact it is most improbable. Ovariotomy performed on nymphomaniac cows causes, among other things, the possibly abnormal milk secretion to return again to normal.

d. *Abortion.* The experiments that were conducted by Schaffer and Hess have shown that abortion, which has such great influence on the quantity of milk, has no influence on its composition. The same statement applies to the retention of the afterbirth, in so far as this causes no general illness.

9. **Exercise and work.** According to a number of different experiments at hand (Dolgich, Torssell, and several others) daily exercise increases milk secretion so that not only the amount of milk increases, but also the total quantity of fats. Sometimes, indeed, the percentage of fat increases, and, as a rule, the percentage of casein diminishes, while the other constituents are affected irregularly.

Work does not necessarily influence the milk secretion to a great degree (Morgen), but generally causes a slight diminution in quantity and there is an increase in the percentage of fat and a proportionate but smaller increase in the percentage of protein and ash. Exhausting work causes not only a material decrease in the quantity of milk, but also a disturbance in the whole secretion, so that even vegetable fats are excreted in the milk in unchanged condition (Dolgich).

10. **Disease of the cow** often brings about a decrease and sometimes even an entire cessation of the milk secretion. In diseases of the udder, the milk undergoes, as will be seen later, very important chemical changes. There is very little positive knowledge of the changes in the composition of milk during diseases that are not localized in the udder. Apparently, it is usually the rule that the daily variations in the composition increase, or, in other words, that the secretion is thrown out of equilibrium. Frequently, in the beginning of disease, there is found an abnormally large pecentage of fat that results from the often sudden decrease of the quantity of the secretion. A salty taste which occurs not infrequently, might possibly mean an increase in the quantity of protein and ash (secretion of blood serum). According to long-standing opinion, milk has an abnormal taste in cases of indigestion of all sorts and under these conditions it also curdles easily.

11. **Medicines.** It is an old opinion that a number of different medicines help to increase the milk secretion and the fat content of milk, and for this reason, so-called "milk powders" are still used. The different materials (fennel, anise, caraway, calamus, bitters, sulphur, antimony compounds, etc.) cannot change the secretion of normal animals, and it is doubtful if they are able to recall the milk secretion after it has been checked through disease.

Other medicines as quinine, belladonna and alum, are supposed to be able to check the secretion as, also, rubbing the udder with opodeldoc, oil of rosemary and the like; but their action is questionable. Drugs like iodine and phosphorus, that act especially on gland tissue, are able to check the secretion or cause it to stop altogether. The excretion of medicines in the milk will be considered later.

Summary. From the above, it is evident that the gland cells of the udder of each cow are adjusted to secrete milk of a rather definite chemical composition which, however, changes during the lactation period, but that these cells react to a number of different influences as a result of which they may temporarily secrete milk of a somewhat changed composition.

As would be expected, the limits for the variations in the composition of cow's milk are reported differently, but milk of a composition that is not included in the limits below is indeed very rare.

Water	Casein	Albumin	Fat	Lactose	Ash
83—89%	2—5%	0.39—0.95%	2.5—7.5%	4—5.8%	0.35—1.21%

It appears that the fat content is subject to great variations; but, if we leave out of consideration old milking cows, these variations are much less. The quantity in milk of solids not fat (casein, albumin, lac-

tose and salts) is far less variable. This applies especially to lactose, which seldom shows the given minimum and maximum percentage. *In the detection of adulterations, the percentage of lactose furnishes, therefore, a better guide than the percentage of fat.*

By mixing the milk of the members of a herd, the individual variations in composition are more or less equalized, so the composition of the whole quantity approaches the average for cow's milk. There are, however, some herds in the milk of which the percentage of fat is much higher than in others; this is a matter of selection or of breed, so, of course, the composition of milk of separate herds will not be the same. As cows usually calve at certain seasons the number of fresh cows and old milkers is not the same at all seasons and, for this reason, the composition of the milk changes. We have the following figures showing the average percentage of fat as found upon daily analyses of milk from three large herds.

	February	May	August	November
a.	3.18	3.42	3.61	3.47
b.	3.69	3.56	3.64	3.77
c.	3.03	3.38	3.51	3.32

In herds *a* and *c*, particularly, calving is distributed unevenly, which causes the percentage of fat to be 0.5 per cent. lower in winter than in summer.

Many of the external influences that have been mentioned as applying to the individual animal and that result in a temporary change in the composition of the milk, may apply, at the same time, to all of the animals in a herd and thereby influence the fat content of the herd milk. This is seen when there is a change of food, disturbance in the stable, storms, extreme heat and so on. However, variations in the composition of the entire quantity of milk caused in such ways are, in most cases,

less than those of single animals, for all members of the herd are not affected in the same degree and quite often the animals react in opposite ways under the same circumstances so that these variations are, in part, equalized after the milk has been mixed together. The larger the herd, the smaller the probability of all its members being influenced in the same way at the same time—and, therefore, the variations from the normal will be so much less. For the same reason, the variations are considerably less when the milk of several, but always the same, herds, is mixed.

So far as we know, there are no data in Denmark concerning the limits of the composition of normal market milk, and these are not sufficiently established in other places—yet it may be assumed that the specific gravity does not vary beyond 1.029 to 1.034, the content of solids not fat does not exceed 8.6 to 8.8 per cent., and the fat varies from 2.75 to 3.5 per cent.[5] [6]

V. CHANGES IN THE SECRETION DURING DISEASES OF THE UDDER

Diseases of the udder that cause material changes in the character and the composition of the udder secretion are: udder contusion, udder œdema, embolism and thrombosis, mastitis, udder tuberculosis, udder actinomycosis and tumors.

1. **Contusions of the udder and the teats** which frequently are caused by cuffing and blows and by kicking and tramping by other cows, ete., produce hæmorrhage of the udder tissues, bloody serous infiltration, or, possibly, death of the udder tissue. The changes in

[5] Jersey herds, etc., not included.

[6] The figures given above relate to Danish cattle, practically all of which are of two breeds which furnish milk containing a much lower percentage of fat than is furnished by most of the herds producing market milk in America. [L. P.]

the secretion consist, in part, of an admixture of blood plasma that is usually invisible and, in part, of blood. The latter may appear in freshly drawn milk as drops of blood or as little clots. When more bleeding occurs, the milk is liable to be diffusely colored reddish and it will color the milk from the other quarters, and even colors the milk of other cows reddish when mixed with it. This admixture of blood cannot be proven by the common guaiac method, for fresh milk will give the same reaction. The proof is most easily gained by means of microscopic examination of the sediment obtained by centrifuging the milk, whereupon the red blood corpuscles are easily recognized among the milk globules.

2. **Udder œdema.** It may be supposed that in udder œdema, which frequently is very severe soon after calving, there is an admixture of transudate with the secretion, but, so far as known, no investigations have been made in regard to this matter.

3. **Embolism and thrombosis** occur occasionally in the udder and cause gangrene of a gland or of a part of one; frequently there is gangrene of the skin and of the teat of the quarter affected. Milk secretion ceases and in its place there is a bloody serous exudate.

4. **Mastitis.** Inflammations of the udder cause quite characteristic changes in the secretion, which often stops entirely to give place to a purulent exudate.

a. *Mucous catarrh.* When drawn, the milk contains small yellowish flakes and lumps which, upon standing, unite into a slimy, dirty, grayish sediment or, together with the cream, form a lumpy, dirty colored layer on the top of the milk. In severe attacks the secretion may be viscid, slimy and sticky.

b. *Purulent catarrh.* In the beginning, the secretion is unchanged but for the presence of small flakes of pus

and fibrin. The milk secretion decreases more or less quickly while the pus cells and fibrin increase in number and, finally, the secretion is replaced by a viscid, whitish or yellowish purulent exudate or by a quantity of yellowish serous exudate which contains clumps of pus and fibrin. In many cases, the udder shrinks and the exudation ceases without the return of the milk secretion; in other cases, milk secretion returns either during the same period of lactation or after the birth of the next calf. In catarrh of the udder, lactose decreases in quantity while the other ingredients—except ash—undergo no quantitative change in the mildest cases. Among the ash ingredients, phosphoric acid, lime, magnesia and potash decrease materially in quantity, while sodium chloride occurs in more than normal quantity. In cases when the secretion is mixed largely with exudate, the quantity of lactose still further decreases and the casein content drops, while albumin and globulin (also fibrin) increase.

c. *Parenchymatous mastitis.* The changes in the secretion correspond essentially with the changes in purulent catarrh, but they occur very suddenly and may disappear as rapidly. The chemical analysis shows changes similar to those in catarrh; the lactose often disappears entirely, while the albumin and globulin increase greatly in quantity. The fats may increase or decrease, the salts change as in catarrh.

d. *Gangrenous mastitis.* The real milk secretion ceases while a bloody-serous liquid is secreted which, on account of the existence of bacteria of putrefaction, is frequently mixed with gas and has the odor of putrefaction.

The chemical changes that take place in mastitis are mainly traced to partial or entire cessation of the real milk secretion and to a simultaneous elimination of

an exudate having a greater or less admixture of pus cells.

e. *Udder tuberculosis.* In many cases, the secretion remains almost imperceptibly changed for a long period, as only very small flakes are intermixed with it. Later on, it decreases in quantity, grows thinner and contains more flakes, and, finally, it is yellowish or reddish, serous, contains clumps and flakes and becomes more like pus. Chemically, the milk gradually undergoes the same change as in cases of other forms of mastitis (Storch).

f. *Actinomycosis and tumors* of the udder no doubt cause changes in the appearance and the composition of the secretion, but no investigations have been made on these subjects.

In mastitis, tuberculosis and actinomycosis of the udder pathogenic bacteria are found in the milk; these will be discussed later.

VI EXCRETION OF FOREIGN MATTER WITH THE MILK

The milk glands may serve to excrete foreign matter which, in some way, has found entrance into the organ, just as the kidneys and other glands do. Such an excretion does not take place to as great an extent as was formerly believed, which, considered from a biological standpoint, seems most natural, for the excretion of foreign matter would prove a great danger to the young animal dependent on its mother's milk for food. Yet there are not a few, and sometimes very harmful, substances that are excreted from the organism through the udder and, therefore, it is one of the problems of milk hygiene to prevent the milk of such cows as are affected in this way, from being used, just as the physician must always consider, in the treatment of mothers and wet nurses, what influence medicines to be given may have on the nursing child.

Reports differ as to what foreign substances are excreted with the milk. These differences of opinion may be accounted for in part by the fact that many substances are not excreted in noticeable quantity until the animal has taken relatively large amounts of them. Sometimes individual peculiarities operate, for it may be that some inflammation not entirely healed, local induration or similar changes in the tissues of the udder, in short, the injuries that remain after mammitis, favor such an excretion.

It has been mentioned before that the milk contains only traces of iron, and this fact alone is a proof that iron compounds are not usually excreted with the milk; even after the consumption of a great quantity of iron during a long time, the iron content does not rise. Concerning other metals, compounds of copper, lead and antimony [7] are excreted only in very small quantity, so that even a prolonged adminstration of these substances to milch cows usually brings about no harmful effects. According to investigations by Baum and Seeliger, the lead content of milk does not increase beyond 0.0009 to 0.002 per cent., even after treating cows with large doses, and this quantity is without importance, even to quite small children.

On the other hand, mercury is easily excreted through the udder, when this substance is taken through the digestive organs or when absorbed after applications to the skin. Iodine and arsenic also easily enter the milk in considerable quantity.

Opinions differ concerning alkaloids. It is a fact, however, that morphine, strychnine, atropine and veratrin are, under certain circumstances, excreted with the

[7] In the older literature, there are recorded a number of observations which indicate that tartar emetic may be excreted with the milk in large quantity

milk in such large quantities as to be dangerous to children. Other substances which can easily be excreted with milk are salicylic acid, carbolic acid, aloes, croton oil and senna, also the active principles of colchicum, hyoscyamus and euphorbium. This is also supposed to be the case with mustard; still there is good reason to believe that it is true only if mustard is taken with the food in large quantities.

It has often been observed that diarrhœa occurs in people who have used the milk of cows fed upon food that is moulded, or that has undergone putrefactive fermentation. It is presumed, therefore, that some of the substances which are formed under these conditions in the food materials of the cow may be excreted with the milk. But it is possible that in such cases there is contamination of the milk from the food during milking and so, in this way, bacterial changes may occur; these have not been entirely excluded.

It was stated above that aromatic substances in forage plants are apparently excreted in slight quantity and may give a "taste" to the milk. [The garlicky taste that is so common in milk in the Spring in the Eastern United States is due to garlic in the pastures.] We find, too, that strongly smelling medicines (asafœtida, ether, certain volatile oils, but not all) that are given to the cows may impart a taste to the milk.

It is highly probable that toxic substances which are formed in the organism during disease, and also such substances that, for example, are reabsorbed from the uterus, may sometimes be excreted in the milk, but there is no definite information on this subject. On the other hand, we know that antitoxins are in part eliminated from the blood of the mother animal through the udder and, through this channel, they may be used by the young to its benefit.

VII. CHANGES IN MILK CAUSED BY MICRO-ORGANISMS

Milk found in the glandular passages and cisterns of the *healthy* udder is usually sterile. On the other hand, the ducts of the teats and, still more, the ends of the teats usually contain bacteria and, therefore, the milk when drawn is infected with them. This is more apt to be the case when the milk comes in contact with the hands of the milkers, or when it is poured into the not always sterile bucket, or when particles of dirt and dust from the udder or the skin of the cow, from the clothing of the milkers or from the air, drop into the milk. Before the milking is finished, a considerable number of different bacteria have been added to the milk and though, for a time, it has bactericidal properties, that is, it is able to kill bacteria or, at least, to prevent their growth, yet the number of bacteria does not diminish noticeably but, in the course of time, increases enormously. Shortly after milking, thousands, even hundreds of thousands, of bacteria may be found in each cubic centimetre.

In inflammatory processes, catarrh, tuberculosis and actinomycosis of the udder, infected wounds at the opening of the teat, etc., bacteria are more or less numerous in the milk before it is drawn. In benign udder inflammations bacteria disappear almost entirely with the cessation of the disease, but occasionally it happens that the bacterial growth continues for a time in the milk contained in the glandular passages, after the secretion has become apparently quite normal and after all signs of inflammation have disappeared.

In general infections, not localized in the udder, as a rule no microbes are excreted with the milk. An exception to this is foot-and-mouth disease (aphthous fever), in which the milk of the affected cows often contains vir-

ulent material, the nature of which is not definitely established. During this disease, several noticeable changes occur in the milk and it is, therefore, very probable that pathological processes take place in the cells of the gland and so an excretion of virus is only to be expected. In other acute diseases, as anthrax, hemorrhages may occur in the tissues of the udder and the admixture of bacteria from the blood follows naturally.

The changes in the milk caused by microbes, and particularly by bacteria, which comprise by far the greatest number of micro-organisms of milk, are very numerous. These are most readily studied by working with sterile milk (the best way is to use milk which was taken from the udder in sterile condition, for milk undergoes quite essential changes when heated) and with pure cultures of bacteria. The most important changes are the following:

a. **The milk is unchanged in appearance,** reaction, odor and taste in spite of bacterial growth.

b. **The bacteria form alkali** (probably ammonia); the reaction grows more and more alkaline and when, after some time, a certain alkalinity is reached, the fat is saponified, the neutral casein-lime compound becomes a base and, as a result of this, the milk is changed to a yellowish translucent, whey-like liquid.

c. **The bacteria split up the lactose, forming acid.** The main product of this division is lactic acid, sometimes d-lactic acid, sometimes l-lactic acid, sometimes a mixture of both, i-lactic acid. The reaction may be expressed by this formula: $C_{12}H_{22}O_{11}+H_2O=4(C_3H_6O_3)$. In fact, however, this process is far more complicated for beside the lactic acids, a number of other compounds are formed in small quantity as by-products: alcohol, valeric acid, acetic acid, succinic acid, carbonic acid, etc. After a certain amount of free lactic acid has

been formed, coagulation of the casein occurs—at room temperature—which either is precipitated as flakes or thickens to a firm, jelly-like substance (curdling of milk) and frequently contains small gas bubbles. At a higher temperature, coagulation occurs in the presence of a smaller percentage of acid. If coagulation is caused by acid alone, the process unquestionably is a simple separation of the casein-lime compound by which the casein, insoluble in water, is precipitated unchanged. When the casein is filtered out and treated with lime water, it dissolves readily. In heating sour milk to 70° C. and above, a real coagulation will occur, however, and the precipitated casein cannot be dissolved in lime water.

After the formation of lactic acid has reached a certain degree (about 0.8 per cent., which corresponds to an amount of acid in 100 c.c. of milk that requires for its neutralization about 100 c.c. of a one-tenth normal solution of Na_2O), the activity of the bacteria ceases, for they cannot thrive in the strongly acid liquid, and the greater number of bacteria rather quickly perish. The different bacteria and yeast fungi which may be the cause of lactic acid fermentation, are not sensitive to the same degree of acidity, and under the influence of these various forms, the milk becomes sour irregularly. These various organisms are influenced very largely by external conditions, in respect to their ability to produce lactic acid, so that sometimes a longer and sometimes a shorter time is required to sour milk, while, in other cases, their ability to produce this change is almost lost. Of the micro-organisms which can produce a lactic acid fermentation, are to be considered the lactic acid bacteria used in creameries (a group, the various species of which have not been definitely differentiated), certain yeast-like fungi (*Saccharomyces lactis* and *Saccharomyces acidi lactici)* the *Bacillus coli communis,* strep-

tococci and the pyogenic staphylococci. Some of these, in addition to producing an acid, develop a ferment which has an action somewhat similar to that of rennet (see below).

d. **Bacteria may form a rennet-like ferment** which causes the milk to form a coagulum of the consistency of jelly, without souring. The ferment, which can be isolated comparatively easily from many bacteria, has effect in the same manner and under similar conditions as chymosin. The precipitated casein cannot be dissolved again by treatment with diluted lime water, and it may be assumed that the ferment has produced a change of the casein into paracasein, whose compound with lime is not soluble, as is well known. A great number of bacteria are known which change the milk in this manner; for example, forms that belong to the typhoid-colon group, many bacilli that are included in the large group of spore-bearing hay bacilli, among them those named by Duclaux, *Tyrothrix tenuis, scaber, filiformis,* etc. Bacilli belonging to this last group are often found in milk, because they are usually frequent in the soil and dust and in the excrement of the cattle, so that they always find their way into the milk when it is drawn. The bacteria under consideration have different influences on the milk. While some, apparently, only cause the milk to curdle (they also separate, at the same time, small quantities of albumose-like substances—probably caseoses and peptone), others are able to redissolve the casein curd by means of a peptonizing ferment (" casease ")—and thus increase the quantity of caseoses. Still others not only dissolve the curd, but also break up the molecule of albumin, so that in the fluid such products appear as peptone, leucin, tyrosin, ammonia, butyric acid, etc. Sometimes the development of butyric acid is so considerable that it

causes the cultures to stink (butyric acid fermentation). Finally, the milk is changed into a watery mixture which contains some fat lumps and has a more or less disagreeable odor.

e. **Bacteria cause coagulation of milk partly by the production of acid and partly by the action of ferments.** Many bacteria as, for example, certain lactic acid bacteria and some members of the colon group, coagulate milk through the production of acid. The precipitated casein is, however, insoluble in diluted lime water, which is an indication that it has been changed, by the action of ferments, into paracasein.

f. **Bacteria may produce a slimy condition in milk or in cream.** In this condition, these fluids become thick and their consistency is so great that long strings may be drawn out. The milk may, at the same time, become acid, although usually this is not the case. There are many bacteria of different kinds that are capable of causing this change. In some cases, the sticky condition comes from the rapid swelling of the slimy capsules of the bacteria, while in other cases the change is thought to be due to unidentified changes in some constituents of the milk, presumably the lactose. It has been thought that this slimy condition may be caused by feeding a certain plant, *Pinguicula vulgaris*, in the same manner that placing the leaves of this plant in milk may produce the change.

Jönsson has found that there are bacteria on the leaves of this plant that make milk slimy or stringy, therefore it is, no doubt, safe to conclude that feeding with this plant is without special significance in this particular. Stringy milk is not unwholesome; in northern Sweden it is eaten in the same manner as coagulated milk is used elsewhere.

g. **Bacteria may cause abnormal odors and tastes in**

milk without producing an alteration in appearance or any of the changes above noted.

The *Bacillus fœtidus lactis* described by Jensen is one of the colon group which has the property of producing in milk an unpleasant odor similar to the odor of turnips, and also a corresponding sweetish, bitter, repulsive taste. This organism, and closely related forms, are probably the real causes of the so-called *turnip taste* of milk. Various micrococci and bacilli are capable of producing a very strong bitter taste without altering the milk in other respects. This change is sometimes due to the production of peptone and, no doubt, to the elaboration of other compounds.

Jensen has described a small bacterium that produces in milk an exceedingly strong *burnt taste* and odor, that resembles the odor and taste of malt. This was so strong as to cause a malty odor throughout an infected creamery. It may be that this bacterium is the real cause of the so-called " malty taste " of milk and butter. Another organism—a micrococcus—was found to give milk an unpleasant fatty, burnt taste.

A bacillus studied by Veigman and Zorn produces an unpleasant *soapy taste,* while a bacterium mentioned by Storch gives rise to an *oily taste* in coagulated milk. Other bacteria cause other less clearly marked tastes and odors that cannot be more definitely characterized than as *unclean.*

h. **Bacteria may cause abnormal coloration of milk;** the most important abnormalities of this class are:

Blue milk is caused by the *Pseudomonas syncyanea (Bacillus cyanogenus),* which produces a grayish color on the surface of milk, while in sour milk distinct blue spots appear, that may become confluent.

Red milk. Certain bacteria, as the *Bacillus prodigiosus* and the *Sarcina rosacea,* grow on the surface of milk,

producing a red color partly as spots and partly as a diffuse discoloration covering the entire surface. The *Bacterium lactis erythrogenes,* isolated by Grotenfeldt, coagulates milk and afterwards dissolves the coagulum into a red fluid.

Yellow milk is produced by a number of organisms that cause the development of yellow or orange-colored spots on the surface. *Bacillus synxanthus* is an example of these organisms that are derived from the atmosphere.

Summary. Milk that is not sterile and that is left to itself, usually undergoes lactic acid fermentation for the reason that lactic acid bacteria are present in large numbers, and by breaking up the milk sugar to form acid, *most of the other forms of bacteria are repressed to a high degree.* Curdled milk may have a clean, sour taste, or a more or less unpleasant, bitter, offensive or oily taste. The latter condition comes from either simultaneous development of other bacteria or from the peculiar effects of special lactic acid bacteria which have caused the acid formation. Coagulated milk left to itself is usually quickly covered with a thin, whitish, consistent layer formed of milk moulds (*Oidium lactis*) and, not infrequently, colored spots appear that are caused by bacteria or fungi, as *Penicillium glaucum.* By degrees the coagulated milk undergoes a putrefactive transformation accompanied by a foul-smelling disintegration of the casein.

Less frequently, the milk quickly becomes slimy or stringy before it has become acid, or while it is beginning to sour. Or it may early acquire a bitter taste and an unpleasant, loathsome odor; very often it does not sour and coagulate, but gradually putrefies: the usual lactic acid fermentation has not appeared and checked the increase of the bacteria of putrefaction.

It sometimes happens that milk coagulates quickly without souring; the coagulum is quite firm, the taste sweetish, often slightly unpleasant. In this case, the lactic acid fermentation has ceased, while the bacteria referred to in paragraph *d* have grown freely. Left to itself, such milk will quickly become putrid.

VIII. CHANGES IN MILK AT HIGH TEMPERATURES

When milk is boiled in an open vessel, it becomes covered with a coating of coagulated casein; after this is removed, a new membrane is immediately formed. If the milk is constantly stirred, the membrane is not formed. The origin of this coating is not entirely clear, but it is possible that it comes from a partial drying of a superficial layer of milk.

Viscosity is diminished upon boiling or long pasteurization, so that boiled milk appears to be thinner than raw milk. This is expressed by Babcock by the following figures relating to two samples of milk tested: 265 raw, and 250 pasteurized; 275 raw, and 257 boiled. The specific gravity of milk changes so little upon heating as to be practically of no account.

Lactose is not changed when simply boiled, but heating at a higher temperature causes a burnt condition (caramel formation) and partial separation into lactic acid, causing the milk to become slightly acid.

Albumin and globulin coagulate upon heating the milk for a short time to 70° to 80° C., and it is probable that casein also undergoes a change, but it has scarcely any significance and has been studied but little up to this time. But if milk possesses a certain degree of acidity, heating causes coagulation of the casein. Boiled milk is not influenced at all, or only very slightly, by rennet ferment; the reason for this is not to be found in change in the casein, but lies in the partial transfor-

mation and separation of the calcium phosphate, as discussed below.

A number of investigations have been conducted to determine whether or not casein, when boiled, undergoes a change in respect to digestibility; although the results do not wholly agree, such a change does not appear to take place.

Pasteurization and boiling cause no material change in the fats of milk; the number of the globules is not reduced, there is no fusing of the globules. Possibly the quantity of volatile acids decreases, but no investigations have been made on this subject.

The salts of milk undergo a change upon heating, as the soluble calcium salts become, in part, insoluble phosphate of lime, especially tricalcium phosphate, $Ca_3P_2O_8$.

As already mentioned, there is much reason to believe that fresh milk contains a peptonizing ferment, *galactase;* if this is the case, boiling or simply pasteurizing must, of course, destroy it. This also destroys antitoxins that may be in milk. It is also safe to say that toxic substances which result from diseases of the cow or come from bacterial growth in milk, are made at least partially harmless by continued boiling.

It is a well-known fact that the taste and odor of milk are changed by boiling; the "boiled taste" appears when it is heated to from 80° to 85° C., but this is less strong than that produced at a higher temperature and is considerably lessened by prompt cooling, immediately after heating. It also appears that the "boiled taste" is less marked when the milk is heated in a closed vessel, so that the absorbed carbonic acid gas may not escape, or when the milk is boiled in the presence of carbonic acid gas.

The action that pasteurization and boiling have upon bacterial growth in milk will be taken up later.

PART III.

HARMFUL PROPERTIES WHICH MILK MAY POSSESS.

Under certain conditions, milk may possess harmful properties. When the cow is diseased, poisonous substances may occur in the milk, and the composition of the milk may differ widely from normal; in udder infections, milk contains an admixture of pathogenic bacteria, and such contaminations may also occur during or after milking. Milk may also take on injurious properties through the action of saprophytic organisms and through accidental or intentional additions of harmful substances, as preservatives. While, in some cases, there is only an altered appearance, taste or odor that serves to make the milk unappetizing and to cause nausea or, perhaps, vomiting, in other cases the milk may be decidedly injurious and cause, under certain conditions, serious illness, even an epidemic.

I. EXCRETION OF POISONOUS SUBSTANCES WITH MILK

It has been stated that different foreign materials may be excreted through the udder tissue. This applies principally to mercury, preparations of arsenic, various alkalies, iodine, irritant substances (euphorbium, etc.) and certain volatile oils. Although these substances are not often present in great quantities, yet milk may be flavored by them, and in this case it may be dangerous for small children and weak persons. Since it is safe to affirm that many materials that are not usually

excreted through the udder may be excreted under certain conditions, and by some cows, it will be wise to regard as suspicious all milk from cows that are treated medically with remedies that are toxic, and to forbid its sale for human food.

Further, since it is quite probable that toxic substances formed in the organism during the course of acute infectious diseases may be excreted through the udder, there is good reason, also, to prevent the use of milk of such animals.

II. ADDITION OF ANTISEPTICS (PRESERVATIVES)

The addition of antiseptics is frequently undertaken by dealers, in order to increase the keeping quality of milk. In some places the addition of preservatives is very common and quite a number of antiseptics are used. As most antiseptics are harmful not only to the lower fungi, but also to the cells of the higher animals, and are to be considered as poisons for animals and man, it is self-evident that the addition of antiseptics should be undertaken with great care or, much better, omitted altogether. In this connection, it must be kept in mind that one person may be peculiarly affected by substances that have no effect on another, and that even a small addition of an antiseptic may be harmful to some people.

The addition of antiseptics prevents acidulation and coagulation, and so may conceal the fact that the milk is already half spoiled. Some substances, in very slight quantity, directly prevent the increase of acid-forming bacteria, and so, indirectly, they may promote the growth of the more resistant bacteria of putrefaction.

In most countries the addition of antiseptics to milk and other foods is prohibited by law.

The preservatives most used are: boric acid, sali-

cylic acid, benzoic acid, potassium bicromate and formalin. Rarely, peroxide of hydrogen and fluorides are used.

a. **Boric acid** is sometimes used as such, sometimes as borax, and is able, when added in the proportion of 0.1 per cent. to 0.2 per cent., to prevent bacterial growth for several days so that coagulation does not take place. It is said that boric acid is a harmless substance, and it is true that it has been used as medicine in quite large doses without injurious effect being perceived. On the other hand, observations and investigations have been made which fully prove that boric acid may cause illness, vomiting and diarrhœa, and if given for a prolonged time, may injure the kidneys and cause somewhat rapid and not inconsiderable loss of weight; the latter depends partly on the fact that the food is not well assimilated and partly on the increase of metabolism (Rubner). Experiments on animals have confirmed the results of these investigations and, indeed, demonstrate that boric acid may even cause a fatal poisoning; for example, Annett fed five kids with milk that was mixed with 1 gr. boric acid to the litre; all five died in the course of 2 to 4 weeks. It may be said, further, that boric acid is excreted from the organism slowly so that the toxic effect is not temporary and transitory, so boric acid must be considered to be an injurious substance and its addition to milk and other food is to be forbidden.

Boric acid may be detected in milk in different ways:

According to Villiers and Fayolle, milk is evaporated to dryness and ignited, the ash is wet with sulphuric acid, 3 c.c. methyl alcohol is added and the solution is distilled until sulphuric acid vapor begins to appear. The vapor is ignited and if boric acid be present, in even a very small quantity, this will burn with a green flame.

Meissl recommends the following method: 100 c.c. of

milk are mixed with milk of lime, evaporated and ignited; the ash is dissolved in a very little concentrated hydrochloric acid; the carbon is filtered out, the filtrate is made slightly alkaline and evaporated to dryness. This salt is treated with a little turmeric tincture and with some very dilute sulphuric acid and is evaporated in a water bath. If boric acid is present, the mass is colored a distinct cherry red.

[Leffmann[8] gives the following method: "A few drops of the sample are mixed with a drop of hydrochloric acid and a drop of strong alcoholic solution of turmeric, evaporated to dryness at a gentle heat, and a drop of ammonium hydroxide added to the residue when cold. A dull green stain shows that boric acid is present."

Richmond[9] offers this method: "To a little milk add a few drops of phenolphthalein, and sodium hydroxide solution, drop by drop, till a faint pink color is produced; place some of the milk in two test tubes, dilute one with an equal volume of water, and the other with a *neutral* 50 per cent. solution of glycerin; in the absence of boric acid the two tubes will have almost the same color, in its presence the glycerin tube will be the lighter, and usually white." L.P.]

b. **Salicylic acid** in a quantity equivalent to 0.04 per cent. can prevent the souring of milk for 36 hours, even when the milk remains at 18° C. It is very hard to dissolve and has not been extensively used to preserve milk.

Salicylic acid has the effect of checking digestion and, with some persons, it may cause irritation of the kidneys; particularly for children, salicylic acid should be

[8] Analysis of Milk and Milk Products.
[9] Laboratory Book of Dairy Analysis.

considered injurious. On this account its use should be prohibited.

The presence of salicylic acid in milk is determined in the following ways:

To 20 c.c. of milk add 2 to 3 drops of sulphuric acid and about the same amount of ether, then shake the mixture. The ether dissolves the fats and the salicylic acid that is present. The ether solution is evaporated and the residue is extracted with 40 per cent. solution of alcohol and filtered. The addition of a few drops of ferric chloride solution to the filtrate gives a violet color if salicylic acid be present. (Remont.)

Girard mixes 100 parts milk with 100 parts water at 60° C., and then adds a few drops of acetic acid and a few drops of a solution of mercuric nitrate, the mixture is then shaken vigorously and filtered. The filtrate is shaken with ether, which dissolves the salicylic acid. The ether layer is then filtered and is evaporated in the air; if salicylic acid be present it remains behind as a white crystalline mass, which, after solution in alcohol, is colored violet by a weak solution of ferric chloride.

c. **Benzoic acid** possesses very powerful antiseptic properties, but is difficult of solution, and is little used as a preservative of milk. Benzoic acid appears to be somewhat harmful to man, and may be poisonous in large doses; there is little definite knowledge as to its special effect on young children.

The tests for benzoic acid in milk are more complicated. 400 c.c. to 500 c.c. of milk is made alkaline by the addition of lime water and evaporated to about one-fourth its volume; this is then mixed with pulverized pumice stone until it forms a thick pap, which is evaporated to dryness over a water bath. The mass is pulverized, moistened with diluted sulphuric acid and shaken with a double quantity of 50 per cent. alcohol.

The alcoholic liquid is neutralized with baryta water and evaporated to about 10 c.c. Dilute sulphuric acid is again added and the liquid is shaken 3 or 4 times with a little ether, which is collected each time with a pipette. The ether is evaporated and the benzoic acid remains in almost pure condition. The mass is dissolved in a little warm water and a drop of a solution of sodium acetate and a drop of a neutral solution of ferric chloride are added. If benzoic acid be present, a reddish sediment of benzoate ferric oxide appears (Meissl); or a little of the dried mass may be treated with a drop of concentrated nitric acid, the latter evaporated and the residue mixed with sand and heated to a high temperature in a glass tube. The benzoin is indicated by the odor of bitter almonds (nitrobenzol).

[The method of Peters, as given by Leffmann, is as follows: "The material is made slightly acid and extracted with chloroform, which is then evaporated spontaneously. The vessel containing the residue is placed in melting ice, 2 c.c. of sulphuric acid added, and stirred until the residue is dissolved. Barium dioxide is dusted into the mass, with constant stirring, until the liquid begins to foam, when 3 c.c. of hydrogen dioxide (3 per cent.) are added drop by drop. The dish is then removed from the cold bath, the contents diluted with water to convenient bulk, and filtered. The acid filtrate is extracted with chloroform. The benzoic acid will have been converted into salicylic acid by the process and the latter may be detected by dilute solution of ferric chloride or ammonio-ferric sulphate." L.P.]

d. **Potassium bichromate** is used by chemists as a preservative for milk samples. It is seldom used as a preservative of market milk. This poisonous material is easily detected, if one mixes together equal quantities of milk and of a 1 per cent. solution of nitrate of silver.

If potassium bichromate be present, the mixture has a yellow or reddish-yellow color.

e. **Formalin or formol** is a 40 per cent. solution in water of formaldehyde. It is a superior disinfectant and is being employed more and more. The presence of 0.008 per cent. formaldehyde (=0.02 per cent. formalin) is able to check coagulation of milk for 100 hours. The addition of formalin causes no change in the fats, therefore it may be used to advantage in samples taken for fat determinations. Formaldehyde has, however, a very decided effect on albumin and as it has a deadly effect on the protoplasma of bacteria, so it is also a powerful poison for the animal cells and tissues. Investigations by Annett have proven that the addition of formalin to milk, even in the proportion of 1 to 50,000 may be injurious, especially for young animals, and even to the point of causing death. The addition of formalin to milk should therefore be rigorously prohibited.

There are many ways of detecting formalin in milk:

1. 100 c.c. of milk are distilled; when about 20 c.c. are evaporated, the distillate is tested by the addition of 5 drops of ammoniacal solution of silver nitrate (1 gr. silver nitrate is dissolved in 30 parts of water and enough diluted ammonia water is added so that the sediment which appears is again dissolved; then it is diluted to 50 c.c.). After the tube has been shaken, it is left standing in the dark for some hours. The presence of formalin is shown by a black sediment or by a black color of the liquid (Thompson).

2. In many cases it is sufficient to add the silver solution directly to the milk, since this either colors it black at once or gives it a brownish color if left standing in the dark.

3. According to Lebbins, a test may be made by the addition of a little resorcin and 50 per cent. solution of

sodium hydroxide followed by boiling. Distinct red color shows the presence of formalin.

4. Denigès recommends the fuchsin method: To 40 c.c. of a 0.5 per cent. solution of fuchsin are added 250 c.c. of water, 10 c.c. of a solution of sodium bisulphite and 100 c.c. pure sulphuric acid. Upon standing, the liquid becomes decolorized. To 10 c.c. of the milk under examination is added 1 c.c. of the prepared decolorized fuchsin solution; after 5 to 6 minutes at the most, if formaldehyde be present, an intense carmine red appears, which becomes violet blue upon the addition of 2 c.c. hydrochloric acid.

[5. Richmond has modified and simplified Hehners' test so that it is most convenient in milk inspection. It is made as follows: To a small quantity of milk, in a test tube, add an equal quantity of water. Pour a little 90 per cent. commercial sulphuric acid down the wall of the tube so that it will form a layer at the bottom. If formaldehyde be present, a bluish or violet zone develops at the junction of the acid and milk. If no formaldehyde be present, a faint, slightly greenish ring forms. This test is effective even when so little formaldehyde is present as 1 part in 200,000.

6. Leffmann [10] recommends the following test, as one of the most delicate and positive: "To a few c.c. of the suspected liquid, a pinch of phenylhydrazin hydrochloride is added, the liquid shaken and a drop of a dilute solution of sodium nitroprusside added and then a few drops of sodium hydroxide. Milk containing formaldehyde gives a grayish green. If the test is applied to the pure solution obtained by distilling the sample a characteristic deep blue is produced."

In distilling milk to obtain a distillate containing for-

[10] Analysis of Milk and Milk Products.

maldehyde for testing it is important to know that, according to the researches of Smith and Leonard, only a small part of the formaldehyde is distilled over; if the milk is rendered alkaline even less is collected, but if the milk is acidulated a larger proportion goes into the distillate. B. H. Smith (as reported by Leffmann) has shown that if 100 c.c. of the milk sample be mixed with 1 c.c. of dilute sulphuric acid, of a strength of one of acid to three of water, and distilled, one-third of the formaldehyde present will come over in the first 20 c.c. of the distillate. L.P.]

f. **Alkalies.** In connection with antiseptics, the addition of alkalies should be mentioned. To be sure, these do not have an antiseptic effect, but still, by the neutralization of the acid formed, they hide changes and conceal the fact that the milk is, perhaps, already spoiled. In this connection the substances to be considered are carbonate and bicarbonate of soda, also chalk and potash. A distinct alkaline reaction of milk to litmus paper points to such an addition of alkali and demands a further test with rosolic acid.

Ten c.c. of milk are mixed with 10 c.c. alcohol (96 per cent.) and a few drops of a 1 per cent. solution of rosolic acid are added. Pure milk will become brownish yellow, while milk treated with alkalies takes on a rose red color. (Hilger, C. Schmidt.)

III. ABSORPTION OF ODORS

Milk possesses a peculiar power to absorb odors. It was mentioned above that goat's milk which is drawn in the stable in which the bucks are stalled absorbs something of the same clinging, unpleasant, characteristic odor. Likewise, cow's milk assumes a foreign odor and a false taste when it stands in a place where there are strongly smelling substances and especially when it is

milked, poured or aërated in such a place. The odor of tobacco is taken up by milk. Oil of turpentine, other volatile oils and asafœtida may give an unpleasant odor and taste to milk. In this respect some of the worst substances are carbolic acid, cresol preparations (creolin, lysol, etc.) and chlorine, when these materials are used for disinfecting stables or dairies. The odor may last in these places for several days and the milk will take the abnormal taste just as long. A mixture of carbolic acid or cresol preparations (crude carbolic acid) and chloride of lime has been used for the purpose of making the disinfectant more effective. This is not to be recommended, as trichlorphenol or trichlorcresol are formed, compounds that have a more penetrating and lasting "carbolic odor" than the separate materials. Milk which is drawn in stables or kept in places which are disinfected in this way is useless, sometimes for weeks.

St. Friis has given a good example of this: a large dairy in Copenhagen was in a state of tumult because some of the customers complained that the milk delivered tasted of carbolic acid. The next day the milk from the farms was examined separately, and it was found that all the milk, about 500 quarts, from a certain herd of 50 cows, smelled and tasted so strongly of carbolic acid that it was declared unfit for use as food. So this milk was churned, as it was also the following days; but the butter had the same taint and was almost worthless. Not till the fifth day was the milk so free from taint that it could be used. This is the explanation of the origin of the trouble: the stable on the farm in question was cleaned and disinfected with a 2 per cent. solution of carbolic acid to which was added a small quantity of chloride of lime. The stable was aired for two days before it was used again,

when the milk in which the defect was discovered was drawn.

IV. TRANSMISSION OF INFECTION BY MILK FROM CATTLE TO MAN

A series of specific diseases are common to cattle and man, and the pyogenic bacteria of man occur in different diseases of cattle. Therefore, the question is pertinent: Can milk, before it is drawn, contain bacteria that are pathogenic for man? It is quite natural that this may occur when the disease affects the udder; but how is it with diseases without this local manifestation? Different answers have been given; some investigators affirm that such an excretion of bacteria regularly takes place through the udder; others (Jensen, Gartner, etc.) insist that this is not the case, that such excretion is generally limited to cases in which, during the course of the disease, local changes appear in the udder tissue (hemorrhage, inflammation), and that anthrax bacilli, for example, by no means always pass from the blood to the milk of the infected cow. An exceptional condition occurs in foot-and-mouth disease, as in this malady the milk contains much infectious matter. But it will be shown later that the milk from cows with this disease shows a decided departure from the normal, so that it is probable that here, too, the excretion of infectious material is associated with pathological change in the udder tissue.

In the case of certain diseases of cows, it may occur that pathogenic micro-organisms become mixed with the milk during milking and, from a practical standpoint, this has, in effect, the same significance as an excretion through the udder.

A more minute account of the diseases of cattle which may cause a direct contamination of milk with pathogenic microbes will be given below.

a. **Tuberculosis.** During recent years quite reliable information has been obtained concerning the prevalence of tuberculosis in cattle, partly from the abattoirs and partly from the use of the tuberculin test.

The abattoir statistics of Denmark show differences in the prevalence of this disease. In Copenhagen, 30 per cent. of the mature cattle are affected; the same is true in Odense, while Arrhus reports a greater percentage.

In consequence of the results obtained from the tuberculin test, Bang regards it as probable that in Denmark half of the small herds of from 1 to 9 members are free from tuberculosis, but only a fourth of the herds of medium size of from 10 to 49 animals are free, and of the large herds only a few are exempt. Concerning the proportions in certain herds, the most of the animals may be healthy and tuberculosis limited to a few individuals, but usually the disease is more widely distributed and, in large herds, often from 80 to 90 per cent., or even a larger number are affected.

The conditions in neighboring countries are about the same. Tuberculosis of cattle, for example, is scarcely less extended in Sweden, North Germany, Belgium and England than in Denmark, while it is less frequent in Norway and South Germany. [This disease is also prevalent in certain parts of America, especially in the leading dairy sections of the Eastern United States.]

The localization of tuberculosis in the udder is of especial interest in connection with milk control, since, when this condition is present, milk is always contaminated with tubercle bacilli. But in certain other forms, as uterine and intestinal tuberculosis, great quantities of bacilli are eliminated with the discharges and the excretions that soil the hind quarters, so these forms may easily be the indirect cause of infection of the milk. This

applies also, to a less degree, to animals that have tuberculous broncho-pneumonia.

There are no reliable statistics to show the prevalence of udder tuberculosis of the cow in Denmark; but the operation of the law requiring the compulsory slaughter of cows with tuberculosis of the udder shows it to be of quite common occurrence. For this cause 407 cows were killed during 1898–99; 592 in 1899–1900; 610 the following year; and 584 in 1901 1902. From Saxony it is reported that from 1888 to 1897, 1.1 to 3.7 per cent. of the tuberculous cows killed in the slaughter houses were affected with udder tuberculosis, and in the whole German Empire in 1888–89, the percentage of udder tuberculosis among the tuberculous cows killed was 1.62. Ostertag rates the prevalence of udder tuberculosis at 4 per cent. of all tuberculous cows. Probably cows reacting to the tuberculin test are not to be understood among these, but only such as are found after slaughter, by superficial examination, to be tuberculous. The number of cows with udder tuberculosis is, without doubt, very great, and in connection with the control of milk one cannot rate the significance of this disease too highly.

There is no information at hand concerning the prevalence of tuberculosis of the uterus. Judging from the numerous specimens showing this lesion, received from the city abattoir of Copenhagen, it appears to be probable that this manifestation is quite common.

In regard to tuberculosis of the intestines, it is known that in mature cattle the disease follows tuberculosis of the lungs and liver, especially in the later stages; and it is recognized with difficulty by clinical examination.

It has been affirmed—within recent years, by Rabinowitsch and Kempner—that the excretion of tubercle

bacilli in milk quite frequently occurs not only from cows that have advanced tuberculosis, but often even from animals which react to the tuberculin test, but show no clinical signs of disease. Numerous investigations (Bang, Nocard, Ostertag and several others) do not agree with the results of Rabinowitsch and Kempner. It appears to be probable that an excretion of tubercle bacilli in the milk takes place only when lesions of tuberculosis are present in the udder tissue; but these may be so young and small that they are not apparent upon clinical examination, and are also difficult to see in dissection. It is not impossible, however, that when bacilli circulate in the blood in great quantity they may pass directly into the milk; but this cannot be a frequent occurrence. As early stages of udder tuberculosis are not revealed by clinical examination, one must act upon the assumption that not only cows with evident udder or miliary tuberculosis give milk containing tubercle bacilli, but also that this may be the case with many cows having advanced tuberculosis, yet without changes in the udder that can be detected by clinical examination. Even cows that are apparently affected with tuberculosis only to a slight degree, or those that appear by clinical examination to be perfectly sound, may give tuberculous milk, in some cases, because very early metastases occur to the udder and in others because this organ appears occasionally to be the seat of primary tuberculous infection.

It has been claimed that cows—even those appearing clinically sound—frequently give milk containing tubercle bacilli after a tuberculin reaction and, therefore, it has been advised to prohibit the use of unboiled milk from such cows, for a few months after the tuberculin test. This assertion is wholly untenable and is completely lacking in proof.

On account of the great extent of tuberculosis among cattle and on account of the frequency with which udder tuberculosis occurs, it is to be expected, as is the case, that market milk very often contains tubercle bacilli in appreciable quantity. It is an established fact that mixed milk from the co-operative creameries contributes to a great degree to the spread of tuberculosis among swine and calves. It has been proven, too, that feeding the dirt removed by the milk separator (centrifugal slime) to swine, may be dangerous. It is conclusively established that the obligatory pasteurization of skim milk in the various creameries, that has been adopted in Denmark in recent years, has greatly aided in checking the spread of tuberculosis among swine and calves.

It is quite natural, under these conditions, that it has also been possible to show that milk sold in the cities contains tubercle bacilli in considerable quantity. St. Friis made some investigations of the milk supply of Copenhagen in this connection; in testing samples of milk from twenty-eight herds in Copenhagen and vicinity, he found four tuberculous, while 33 samples from small farms in Seeland were shown to be incapable of producing tuberculosis when inoculated upon animals. These results are better than those reached elsewhere through similar investigations. In the table on page 75, essentially after Klimmer, a review is given of such results from different cities.

These results were gained chiefly by intraperitoneal inoculations of milk upon rabbits and guinea pigs and are, therefore, to be regarded, to a great degree, as authentic.

The tubercle bacilli are sufficiently resistant to live through the souring and other processes necessary in the manufacture of milk into butter and cheese, so that but-

ter, as well as cheese, may contain tubercle bacilli. In some places this has been proven by a comparatively large number of butter tests.

In this connection, the question is naturally raised: Is tuberculosis transmissible to man through milk and

City.	Number of samples examined.	Number of samples in which tubercle bacilli were found.	Examination made by
Copenhagen	28	4	St. Friis
Copenhagen	33	0	St. Friis
Berlin	40	3	Obermuller
Berlin	13	8	Obermuller
Berlin	64	9	Petri
Halle	9	2	Bnege
Genoa	33	3	Massone
Schwäbisch-Gmünd	43	5	Ott
Schwäbisch-Gmünd	28	3	Ott
Milan	54	4	Fiorentini
St. Petersburg	71	4	Sacharbekoff
Dorpat	40	1	Kudinow
Krakau	60	2	Bujwid
Wilna	22	12	Nonewitsch
Helsingfors	21	8	v. Hellens
Paris	30	6	Girard
Liverpool	144	3	Boyce, Woodhead
Liverpool	24	7	and others
Liverpool	55	3	Delépine
Liverpool	125	22	Delépine
Liverpool	159	12	Boyce
Liverpool	91	16	Boyce
London	100	7	Klein

dairy products? Avian tuberculosis has been shown to differ essentially from tuberculosis of mammals; then is tuberculosis of man identical with that of cattle? With the discovery of the tubercle bacillus, this question was answered affirmatively, and this gave impetus to the movement for meat inspection and dairy inspec-

tion. Through the discovery of the prevalence of feeding tuberculosis in swine, horses and cattle, veterinarians have emphasized the great danger that may come to man by the use of meat and, especially, of the raw milk of tuberculous animals. Many physicians have taken the same ground, while others would minimize this danger to a great degree, or combat its existence entirely, by pointing out the great infrequency of primary intestinal tuberculosis in man, and they claim that tuberculosis of man, almost without exception, begins in the lungs and is an infection by inhalation. There is still disagreement on this subject. It cannot be denied that there is a remarkable difference between the prevalence of feeding tuberculosis of calves and pigs on the one side, and the prevalence of the unmistakable feeding tuberculosis of man.

Since avian tuberculosis has been shown to differ from tuberculosis of mammals, and since tuberculosis of dogs is not transmissible to rabbits, but evokes only a temporary local process (Jensen), it has become necessary to consider the differences between tubercle bacilli from different sources and, especially, to study experimentally the relation of cattle tuberculosis to tuberculosis of man. Of investigations undertaken in this line, those of Th. Smith and Frothingham are valuable because they show a certain difference in the bacilli of cattle from those of man and prove that tubercle bacilli of man possess but slight virulence for cattle. This question has become especially interesting since the tuberculosis congress in London in 1901, when Koch gave the results of experiments that he had conducted in connection with Schütz and, on the basis of these, he believed he could affirm that tuberculosis of man is not transmissible to cattle and, on the other hand, that tuberculosis of cattle is probably not transferred to

man. In support of the latter statement, Koch produced statistics which were said to prove the great infrequency of man's infection with tuberculosis through food.

It is evident that the question of the identity or non-identity of tuberculosis of man and cattle is of great importance in the control of the milk supply. Koch, consequently, drew the conclusion from his investigations that the control of meat and milk, so far as tuberculosis is concerned, is superfluous and unnecessary. Therefore, we have all the more reason for a closer consideration of the three questions placed in the foreground by Koch's report.

1. Is tuberculosis from food infection rare in man?
2. Can human tuberculosis be transmitted to cattle?
3. Can it be proven that tuberculosis of cattle is transmissible to man?

If we first consider the question of the frequency of the occurrence of tuberculosis in man from infection through his food, it will be seen at once that differences of opinion exist concerning the modes of infection. The usual opinion (until quite recently) is that by far the greatest number of cases of tuberculosis in man are caused by inhaling the dry bacilli; there is, however, opposition to this view. Ribbert and Aufrecht have concluded that tuberculosis of the lungs is of embolic origin and others (Grawitz) have found the tonsils to be among the most favorable places for the admission of bacilli. Observations on animals, particularly on swine and monkeys, caution us not to draw definite conclusions in relation to the mode of infection from the gross anatomical lesions. Thus, for example, with swine that are infected almost exclusively through the digestive canal, tuberculosis of the intestines is an exception, while miliary tuberculosis of the lungs often leads to a rapidly developing caseous pneumonia.

Moreover, tuberculosis is undoubtedly not so infrequently caused by the food (primary tuberculosis of the intestines and mesenteric glands) as Koch affirms. The available statistics concerning the prevalence of abdominal tuberculosis differ considerably. While the English tables show the prevalence of " tabes mesenterica " at about 10 per cent. of all cases of tuberculosis and at about 30 per cent. of all cases of tuberculosis in children, the corresponding figures for Berlin are (1898) 1.8 per cent. and 2.8 per cent., for Paris (1897) 1.33 per cent. and 1.65 per cent., for New York (1899) 0.47 per cent. and 2.86 per cent. and, finally, for Boston (1900) 1.14 per cent. and 4.35 per cent.[11]

This difference is, no doubt, largely due to different interpretations of the post-mortem findings [and to the different degrees of prevalence of tuberculosis among cattle] but a partial explanation may also be found in the fact that most of the milk in England is used in the raw state. From some of the German states there are reports (Heller and Seitz) concerning the rather frequent occurrence of "alimentary tuberculosis" in children. As for Copenhagen, Fibiger has stated that primary infection of the intestines and of the mesenteric glands is not infrequent with children. Cases also occur in adults that are most naturally pronounced to be primary intestinal tuberculosis.

In reference to the second question—the possibility of the transmission of human tuberculosis to cattle—investigations have been going on for some time that prove that transmission may be effected by inoculation. After Koch's report appeared, a great number of experiments were undertaken to throw light upon this question, the results of which are partially published. Fib-

[11] Salmon: Relation of bovine tuberculosis to the public health. 1901.

iger has given a review of these: in 61 series of experiments, 81 calves, heifers, cows and oxen were inoculated with human tuberculosis; in 41 experiments on 51 animals the result of the inoculation was positive. In many cases the inoculation caused only local processes extending to near-by glands, but the experimental animals were all killed comparatively early, so that the disease could well have spread further if the animals had lived longer. As is known, tuberculosis of cattle frequently remains local for a long time. Sometimes the inoculations caused violent tuberculosis in the experimental calves, and this was particularly the case when the inoculation material came from patients affected with "feeding tuberculosis." (Ravenel, Wolff, Fibiger and Jensen, Westenhoeffer.)

The clinical observations that may be cited in answer to the third question seem to prove that bovine tuberculosis is transmissible to man. There are many observations, principally upon veterinarians and butchers, of tuberculous inoculation communicated to the hands and fingers through cuts while working with tuberculous organs of cattle. In some cases these were only local lesions that were healed by surgical means; in others, the disease extended to the sheaths of the tendons and glands, and in still others, in the course of time, it appeared to develop into lung tuberculosis. Greater interest attaches to cases of feeding tuberculosis which may with great probability be traced to infection through milk of tuberculous animals. A large number of such cases have been given, from which the following have been chosen:

1. The 17-year-old daughter of Prof. Gosse died of abdominal tuberculosis after drinking milk from cows affected with udder tuberculosis. Other sources of infection could not be discovered.

2. Olivier's observation concerns one of the best proven cases

of transmission by milk: In a boarding school 12 young girls became ill with signs of intestinal tuberculosis, and 5 of them died. All came from healthy families and no source of infection was found but one cow which supplied milk for the school and was shown to be affected with tuberculosis of the udder.

3. Demme has reported the following: In the children's hospital Bern, four children died of intestinal and mesenteric glandular tuberculosis. He was able to exclude all other sources of infection and to prove that the milk came from tuberculous cows.

4. Hills tells of a 21 months old child that was affected with intestinal tuberculosis three months after making an eight-day visit to an uncle where it had drunk the milk of a cow having advanced tuberculosis. The child died of tuberculosis. Other sources of infection were excluded and another child fed only with sterilized milk remained healthy.

5. Ernst reports that three children of the same family died of tuberculosis after drinking milk from a cow that later died of general tuberculosis with udder involvement.

Leonhardt, Sonntag, Hermsdorff, Klebs, Rotch, Lydtin and Stang, Johne and many others have reported quite similar observations.

Of particular interest are the cases reported by Ravenel, Fibiger and Jensen, and many others, of tuberculosis of children with prominent lesions in the digestive canal, while the tubercle bacilli present were so virulent for cattle that the origin of the cases in question were referred, with the greatest probability, to infection through the milk.

If one considers that feeding tuberculosis is by no means infrequent in man, and occurs quite frequently in children, that human tuberculosis is often transmissible to cattle, and that clinical knowledge argues for transmission of bovine tuberculosis to man, and if one considers that tubercle bacilli from cattle have been proven at least as dangerous and generally more virulent for all animals than tubercle bacilli from man, then milk containing tubercle bacilli must be regarded as most

dangerous to health. Therefore, it must be one of the most important purposes in milk control to prevent the sale of such milk.

It is a difficult task to detect tubercle bacilli in milk. Intraperitoneal injections of the milk into guinea pigs and rabbits may be made, but sometimes many of the animals die from other infections (cocci; other bacteria). Sometimes so long a time elapses before the results are available that the experiment has lost much of its practical value. Moreover, certain similar bacteria (acid-fast bacteria) may cause alterations in the experimental animals which can hardly be distinguished from tuberculosis. The detection of tubercle bacilli in milk by microscopic examination is difficult; a direct examination will very seldom give results; so one must depend either on centrifuging, whereby all the little flakes to which the bacilli usually adhere may be thrown down, and then examined, or other means for separation must be used (see below) so that the bacilli may be precipitated without too great a quantity of sediment.

Since the number of tubercle bacilli in mixed milk is, at most, but small, only a positive result of the examination can be final, and even then the result is doubtful since, as mentioned before, "pseudotubercle bacilli" may appear in milk (see below) which are like the tubercle bacilli in respect to staining and are similar also in morphology.

We must, therefore, depend on the clinical examination of the cows in the herd itself, if we would check the passage of tubercle bacilli into milk. This inspection must be directed especially to tuberculosis of the udder, uterus and intestines and, at the same time, to miliary tuberculosis and to all cases of lung tuberculosis sufficiently developed to cause the appearance of clinical signs. But the inspection must not be clinical alone; in

respect to the first forms of tuberculosis mentioned, it must be microscopic as well, for tubercle bacilli may be found in the milk, in the uterine secretion and sometimes in the excrement when the clinical symptoms are such as merely to arouse suspicion. Such an examination of the herd, to be efficient, should occur frequently, at least every fortnight, since this disease, and especially tuberculosis of the udder, may develop materially in this time.[12]

It can hardly be stated, in general, how strict the regulations regarding tuberculous animals should be. In some countries it is only forbidden by law to use milk unboiled from cows with udder tuberculosis. Milk from cows with tuberculosis of the uterus, of the intestines and miliary tuberculosis, and also from cows that are cachectic, should not be permitted to be sold. It would be best, if it could be arranged, to allow the sale of milk from herds in which there are tuberculous animals only under declaration of the condition of the herd; but on account of the great extent of tuberculosis no such requirement has been made. It is a reasonable and, at the same time, an absolutely necessary requirement that the so-called "nursery milk," milk intended especially for small children and invalids, should come from a herd which is entirely free from tuberculosis, that is, a herd composed of cows none of which have reacted to the tuberculin test.

Tests.—The discovery of tubercle bacilli in the milk of individual cows with advanced udder tuberculosis and in the discharge from the uterus, is usually easy. A small quantity of the fluid or a little flake or lump is spread upon a cover glass, it is fixed in the usual way in the flame and then stained according to one of the methods given below.

[12] This relates to herds known to be infected. [L. P.]

1. *Ziehl-Neelsen method.* One grm. of fuchsin is dissolved in 10 c.c. alcohol and 100 c.c. 5 per cent. phenol water and the solution is filtered. By means of a pipette, a liberal quantity of this staining fluid is dropped on the cover glass which is held by pincers above a flame a couple of minutes until the fluid boils briskly, but without drying. Then the cover glass is rinsed with water and treated for a few seconds with 25 per cent. sulphuric acid and again rinsed with water. If the red color is still distinct, the treatment with acid is repeated and the cover glass is rinsed carefully with a little alcohol. Finally, a few drops of watery solution of methylene blue are dropped upon it, after which it is again rinsed with water and mounted.

2. *Kitt's method.* To 100 c.c. saturated anilin water are added 1 c.c. of a 1 per cent. sodium hydrate solution and 4 to 5 grm. of fuchsin. Or, the above mentioned phenol-fuchsin solution may be used. The cover glass is treated as described above, then rinsed and dipped for one-half minute in a fluid consisting of 50 c.c. alcohol, 30 c.c. water and 20 c.c. nitric acid, to which has been added as much methylene blue as the fluid will dissolve. Finally, the slide is rinsed with water.

3. *Czaplewski's method.* The staining is done by heating with phenol-fuchsin solution as given above. Allow the staining fluid to run off and, without rinsing, dip the cover glass six to ten times into a concentrated alcoholic solution of fluorescein (1 grm. in 100 c.c. alcohol). The double staining comes from repeatedly dipping the cover slips in concentrated alcoholic solution of methylene blue (5 to 100); then they are rinsed in water. By this method, a decoloration of tubercle bacilli is avoided with certainty.

In all cases, the preparation is mounted and ex-

amined in the usual way with an immersion lens and Abbé condenser. The tubercle bacilli are colored red, other bacteria and the rest of the preparation are colored blue.

So-called "acid-fast" bacilli may occur in milk and butter as well as in the excrement of the cow. These bacilli, which by the above methods are also colored red, are difficult to distinguish with certainty from the real tubercle bacilli, even by microscopic examination, although they are usually thicker and shorter. Unfortunately, we know but little of the conditions governing their occurrence in milk. There is reason to believe that they usually occur as a result of accidental contamination after the milk is drawn. In order that one may be quite safe in his conclusions from this examination, and be able to avoid confusing the acid-fast and tubercle bacilli, the udder secretion or the discharge from the uterus that is to be examined microscopically must be taken as pure as possible in a clean tube and, if the examination cannot be made at once, an antiseptic (a little ether or chloroform, a few drops of formalin) should be added. Acid-fast bacilli accidentally added, will not increase under these conditions, and their number will always be so small that they can hardly be detected. It is, however, not wholly disproven that such bacilli may appear in the milk before it is drawn. De Jong has reported a case of mastitis caused by acid-fast bacilli, but this is the only case of the sort reported up to this time. From knowledge gained during the last four or five years in the experimental laboratory of Copenhagen from investigations of milk samples and the control of the diagnosis of udder tuberculosis from small samples of tissue from condemned and slaughtered cows, it follows that errors very seldom occur as a result of confusing these organisms.

When it comes to the examination of milk of normal appearance, the question is usually more difficult, because the number of tubercle bacilli is less. A direct microscopic examination of the milk is rarely useful; it is better to pour a little of it on a dark surface and pick out with a needle the small flakes which are usually present and form the little lumps of fibrous exudate to which the bacilli adhere. Still better results are reached by centrifuging the milk and examining the sediment. Any milk centrifuge may be used for this purpose (including those used for determining the amount of fat) and it may be driven by steam or by hand power. Of course, a large centrifuge of high speed is best.

Instead of the centrifuge, the separation of tubercle bacilli by other means has been suggested.

For this purpose Biedert employs the following method: 100 c.c. milk are mixed with 4 to 8 drops of solution of sodium hydroxide; the mixture is well shaken until the small flakes and lumps are dissolved, then it is boiled. The cloudy fluid is poured into a conical glass and left standing for some time. The sediment that collects in the point of the glass may be drawn off by a pipette and examined microscopically.

The practice has also been followed of submitting the milk to special treatment with chemicals before it is centrifuged.

Thus, Ott mixed together 25 c.c. milk, 2 c.c. concentrated ammonia water and 100 c.c. of a mixture of equal parts of ether and petroleum ether, in a separator flask with a glass stopper. After being shaken and allowed to stand, the ammonia-casein solution, in which the bacilli are found, is drawn off from the bottom and centrifuged.

Hammond's method is as follows: 100 c.c. of milk are mixed with 5 c.c. of phenol; 15 to 30 c.c. of the mixture

are placed into two tubes and centrifuged for 15 minutes. The fluid is poured off and 3 c.c. of a 5 per cent. solution of potassium hydroxide are added to the sediment. After violent shaking, the liquid is allowed to stand 2 to 3 minutes, then 15 c.c. of water are added to it; it is shaken and centrifuged 20 minutes. Then, 15 c.c. of the liquid are drawn off from above, while the residue is examined microscopically in the usual way.

The detection of tubercle bacilli in milk by cultivation is most difficult and without practical utility. In doubtful cases, where the result of the microscopic examination is uncertain, it is advantageous to "harpoon" the udder, thereby removing a small sample of the deep tissue of the udder for examination microscopically or by the inoculation of experimental animals, as guinea pigs.

Statements of the temperature at which tubercle bacilli are killed, vary greatly. While, in the first instance, Bang and other investigators found that momentary heating to 85° C. killed, Legay and Bech reported that brief boiling was not always sufficient, and Völsch found that even repeated boiling would not always kill tubercle bacilli. On the other hand, Th. Smith reached the conclusion that even a far lower temperature than those originally given would kill with certainty if the formation of a pellicle during heating was prevented. According to the most recent investigations, carried out with the greatest accuracy by Bang and Stribolt, it is to be considered as proven that heating at 65° C. for 5 minutes or momentary heating at 70° C. kills the bacilli with certainty and that the former uncertainty on this subject arose principally from faulty methods in the experiments. The observations by Legay, Bech and several others show, however, that in practice a very high degree of heat must be attained to be safe, and that

even boiling for a short time without especial precautionary measures, is not always sure to kill all bacilli, because there is a part of the milk (little drops on the upper part on the vessel, bubbles, scum or froth on the surface) which is not thoroughly heated. It is, therefore, a matter of great importance to determine whether the forms of apparatus used for pasteurization are really so constructed that all of the milk is equally heated to a desired temperature. At present, nothing definite can be said about this, since no investigations have been made to determine the amount of froth formation and the temperature the froth reaches in the different forms of apparatus. When market milk is pasteurized the functional capacity of the apparatus should be very carefully tested.

b. **Foot-and-mouth disease.** It has long been known that milk from cows with foot-and-mouth disease is infectious, and may carry the disease to man. A hundred years ago, in South Germany, the use of milk from such cows was prohibited for use as food for man. In the lighter forms of the disease the milk remains unchanged, but with cows badly affected, there is not only a decided diminution in quantity, but its appearance and composition are changed. In such cases, the milk becomes thin, separates a slimy layer of cream, of dirty color, and there is quite abundant sediment or, as happens infrequently, it becomes richer in fat with a simultaneous falling off in quantity. Under the microscope, leucocytes and broken-down tissue-cells are found in greater quantity than usual, sometimes red corpuscles also. The milk contains a greater quantity of albumin and globulin than usual, so that when boiled, large clumps and flakes separate and the sugar and casein fall off in quantity—all changes which are symptomatic of an admixture of inflammatory exudate.

Just how often the milk of the affected cows is virulent, is not known. Apparently, this is frequently the case, and certainly it is when the milk shows the changes mentioned. The virus may, moreover, enter the milk as it is being drawn, if vesicles occur on the teats or udder. The quantity of milk decreases noticeably during the course of the disease and it seldom reaches its original flow after recovery.

This disease is very easily communicated by the milk to other cattle, to swine and, as is known, to man. Children are especially susceptible. Brussenius and Siegel have collected a large number of the cases mentioned in the literature of foot-and-mouth disease in man. During the years from 1878 to 1886, 16 different epidemics of the disease in man were observed. Not only were all the members of single families attacked, but also numerous inhabitants of whole villages and towns. During one epidemic, 36 died; during another, 23 and during a third, 16. All the epidemics occurred simultaneously with foot-and-mouth disease of cattle in the affected districts and, almost without exception, the infection came from the use of raw milk. From 1886 to 1896, 172 cases in man were reported in the annual reports of the German Imperial Health Office, 66 of which were traced to infection through milk, while one case occurred from the use of butter made from the milk of an infected cow.

The course of the disease in man may be light or severe and, as said, the disease may end in death. The symptoms are: fever and weakness, conjunctivitis, formation of vesicles on the mucous membrane of the mouth, the lips, the ears, the nose, fingers or, less frequently, on other places on the body; besides, nausea, vomiting, diarrhœa; sometimes redness of the skin and arthralgia. It is transmissible from man to man.

The virus of foot-and-mouth disease may occur even

in butter, buttermilk and cheese, since it is not killed by the treatment which milk undergoes in their manufacture.

This virus, the appearance of which is wholly unknown (probably on account of its ultramicroscopic size), is not particularly resistant. It has been proven by experiments made during recent years in Germany that the virus dies after 10 minutes' exposure at 70° C. and by being heated to 100° C. for an instant. Experiments made in Denmark seem to have shown that pasteurization at 80° to 85° C., as is done in our coöperative creameries, is, without doubt, enough to destroy the virus.

c. **Cowpox.** This disease attacks particularly the teats of the cow, and therefore it cannot be doubted that during milking the virus held in the vesicles sometimes falls into the milk. Since the vaccine virus is known to be very potent, and since man is peculiarly susceptible to it, it is evident that the disease is transmissible through milk to man. But, while there are numerous examples of direct infection on the hands and face of the milker, there are only a few observations of an infection through the use of such milk. The infrequency of such cases may come partly from two conditions, namely, that most persons are early immunized by compulsory vaccination and that small children usually drink the milk after it has been boiled or, at least, heated.

Among the examples of this disease in children, which have occurred through the use of milk from infected cows and which are to be taken as unmistakable transmission of the disease, the following observation by Stern may be given: Cowpox broke out in a herd of milch cows; a large number of children that had used milk from this herd became affected with an eruption on the face, which healed, leaving scars.

During the course of cowpox, milk may undergo quite noticeable changes in that it becomes thin and bluish and coagulates very easily. This change has not yet been closely studied, and it does not appear to be constant.

d. **Anthrax.** During the course of anthrax, the secretion of milk falls off suddenly and decidedly. The milk secreted is thin and its composition is supposed to be abnormal. According to a report of Monatzkows, the percentage of sugar and fat is increased and the albumin decreased. Perdix states that the milk contains ammonia.

Chamberland and Roux, Nocard and several other investigators have observed that the milk of cows affected with anthrax contains virulent bacilli. According to the experiments of Monatzkows and of Jensen, this is not always the case. Since the milk is often mixed with blood, following slight hemorrhages in the udder tissue, it is probable that the admixture of bacilli occurs only when such hemorrhages take place.

As anthrax bacilli are able to penetrate the mucous membrane of the digestive canal in man, the milk of a cow suffering with anthrax is to be considered very dangerous. This was mentioned long ago by Heusinger, but so far as is known to the author there is only a single questionable observation of such transmission (Karlinski).

The milk from healthy cows in a herd in which a case of anthrax has occurred must be regarded as harmless, for the disease is accompanied by striking symptoms and bacilli are not to be found in the milk before the late stages of the disease. Cows that still appear healthy, give milk free from bacilli even though they be affected. Apropos of this, the following statement is contained in Section 26 of the instructions to the Danish veterinary police: " Milk from sick [anthrax] animals

must not be used for food for man or beast. The owner may dispose of milk from the healthy members of the herd—in so far as the sanitary police give no other order—unhindered, under the condition that he pledges himself to observe closely the condition of the health of the herd and to separate at once those animals which show suspicious symptoms, such as lack of appetite, cessation of rumination, diminution of milk yield and the like. Milk from animals that are separated must not be mixed with that of the healthy animals."

The health authorities may, however, have good reason to forbid the sale of unboiled milk in cases when the disease breaks out violently in a herd, as then the danger exists that bacilli may enter the milk when it is drawn, for the sick animals excrete bacilli with the bloody excrement and the stable, in spite of all care and disinfection, may be so thoroughly infected that there is the possibility of contaminating the milk.

c. **Rabies.** The virus of rabies, yet unknown, is especially associated with the central nervous system and the salivary glands. Frequently it may be found in other glands and even in the udder. A number of observations by Nocard, Perroncito, Bardach and several others, have proven that the virus may be secreted with the milk. All attempts to convey the disease to healthy animals, through food containing infectious material, have thus far resulted negatively, and hence numerous opinions have been expressed to the effect that there is apparently no danger to man in the use of milk from cows that have been bitten by a mad dog and that are themselves rabid.

Yet, since the possibility is always present that infection may occur through a slight lesion of the mouth or pharynx, milk from cows infected with rabies (cows that have been bitten by rabid dogs) is to be regarded as most dangerous to health.

f. **Lung plague.** According to the few investigations that have been made, milk undergoes a considerable change during the course of this disease. The fat content is lessened and the albumin increases in quantity. After standing, the milk is quickly separated into a layer of cream and a lower serum-like layer. Haukold affirms that the milk has a peculiar odor and taste, and may cause vomiting in man. Wiedermann, Lécuyer and Randou have observed some cases where, according to their opinion, lung plague has been carried to children through the use of milk from infected cows. Though at least one case, in respect to its pathological anatomy, showed great similarity to the peculiar pneumonia that occurs in this disease of cattle, it should not be regarded as established that man is susceptible to this disease, and especially is transmission through milk unlikely, because it is not possible to prove the presence of the specific virus in the blood or in the milk by inoculation.

The changed condition of the milk is enough, however, to prohibit its use. But such an interdiction is unnecessary in almost all civilized countries on account of the regulations of the veterinary police regarding this disease.

g. **Actinomycosis.** Actinomycosis belongs to the comparatively frequent diseases of the udder of the cow where it apparently originates primarily. Sometimes it appears as miliary actinomycosis with a number of quite small lesions distributed throughout the gland affected, and in this form it may resemble a fresh udder tuberculosis. More often, actinomycosis appears as single or multiple nodules from the size of a nut to that of an egg—these are surrounded by newly formed connective tissue and may break through the skin of the udder.

There are no recorded investigations concerning the

changes in milk secretion during this disease, nor have the actinomyses or ray fungi yet been found in milk, in which they probably occur. Man may be infected through the digestive canal (the mouth and intestines), just as cattle are, and on this account the possibility of contagion through milk should not be disregarded. Therefore, milk from cows affected with udder actinomycosis (which, however, is not often diagnosed in living cows) should not be used as food for man.

h. **Inflammation of the udder (mastitis).** The *forms* of inflammation of the udder occurring in the cow may be divided into the following principal classes, which differ chiefly according to the grade of inflammation, the extent to which the milk secretion is checked and the character of the exudate:

1. Mucous catarrh;
2. Purulent catarrh;
3. Parenchymatous, purulent mastitis, ultimately accompanied by abscesses;
4. Gangrenous mastitis.

These forms cannot always be distinctly separated. The changes caused through inflammation of the udder, in the chemical composition of milk were described above.

The various forms of mastitis are of microbic origin. There are many kinds of *bacteria* which, if admitted to the milk cistern, may cause inflammation of the glands and, upon examination of the spontaneous cases, quite a large number of mastitis bacteria have been found, chiefly such as cause inflammation elsewhere in the organism. By far the most cases of udder inflammation arise from bacteria which belong to one of the following groups:

1. *Streptococci,* which usually cause chronic mucous (slimy) or purulent catarrh, ending with atrophy of the

udder tissue and agalactia. More rarely, streptococci occur as causative factors of a mild catarrh of the udder.

2. *Staphylococci,* which sometimes cause a milder form of udder catarrh, and sometimes cause a light or moderately severe parenchymatous inflammation, which may end in recovery, in abscess formation or in contraction of the udder. The *Staphylococcus pyogenes aureus* and *albus* are found, but others occur as well. In this group, as is known, the differentiation is difficult.

3. *The colon group.* The parenchymatous forms of mastitis caused by organisms of this group may be mild, medium or severe, and they may end in spontaneous recovery, necrosis, gangrene and formation of abscesses, or in induration. The systemic manifestations may be very marked, and the infection may even result fatally.

It is impossible to determine by clinical signs which bacteria are present. In order to decide this, it is necessary to resort to microscopic and bacteriological examination.

It is important for us to note that streptococcus forms of mastitis not infrequently appear as a contagious disease and little by little extend to a large proportion of the cows of the herd. It is also important to note that streptococci in certain forms of mastitis may continue in the secretion after the principal clinical signs have disappeared, and are able to again cause a breaking out of inflammation of the gland when lactation begins anew.

The admixture of pus gives the milk a most unappetizing appearance, often causes an unpleasant taste and frequently causes it to putrefy quickly, or to curdle. On this account, it is necessary to prevent the mixing of the secretion from infected glands with the other milk. Be-

sides, it is highly probable that the pus itself may be harmful if it is taken by small children. The greatest weight, however, is to be placed on the possibility that the bacteria contained in the mastitis milk may cause disease in man, if they are taken into the digestive canal. We know that staphylococci and streptococci which have reached the human digestive canal in other ways have sometimes proven to be most virulent, and we may suppose that the same is true of mastitiscocci and possibly also of the coli-aërogenic forms.

Inflammation of the udder is a very common condition of the cow and, therefore, it might be expected that there would be frequent opportunity to observe the harmful effect of infected milk upon man. That this is not the case may be due partly to the relatively low virulence of some of the mastitis bacteria for man, and because it is only in the rarest cases that it is possible for the physician to gain sufficient information to trace the special disease of his patient to the use of milk, and then to trace this to a certain diseased cow. Further, there is the fact that most milk for small children is used boiled, so that the bacteria present have, for the most part been killed.[13] As examples of the danger of using the milk from cows with mastitis, the following cases of disease may be mentioned:

1. In Christiana, in 1894, A. Holst observed acute catarrh of the stomach and intestines in four adults and four children, who lived in three separate houses. They had all drunk milk some hours before the attack. Those members of the household who had taken little, or boiled, milk remained in good health. The milk in question had a normal appearance, but was slightly acid and contained masses of short or long streptococci. The milk

[13] In Denmark, as in other countries of Continental Europe, very little raw milk is fed to children. [L. P.]

came from a herd in which a cow with mastitis was found, and it was explained that her secretion had been mixed with the common supply that very day.

2. Prof. Holst has also reported the following cases: Five persons were attacked with acute catarrh of the stomach and intestines a couple of hours after drinking milk from the same milk shop. The milk came from a herd in which a case of inflammation of the udder, caused by streptococci, was discovered by special investigation. Here, also, it was shown that mastitis secretion had been mixed on the same day with the other milk, through the mistake of a new servant.

3. Dr. Johnnesen observed, likewise in Christiana, two cases of diarrhœa (mother and child) which began two hours after the use of raw milk which contained numerous diplococci and streptococci. The examination of a herd that had furnished the milk revealed that two cows suffered with inflammation of the udder, and in their secretion these cocci were found. Apparently still other cases arose from the use of the same milk, but these were not investigated closely.

4. Four children of one family were attacked with acute catarrh of the stomach and intestines, also a child of another family. The disease, in both cases, was traced to the same milk. This appeared by superficial examination to be normal, but by microscopic examination it was shown to be rich in diplo- and streptococci. Here, also, it appeared with practical certainty that the harmful quality of the milk was derived from a case of mastitis.

5. In Stockholm [14] the members of nine families became ill with the following symptoms: fever, languor, faintness, nausea, vomiting and diarrhœa, together with

[14] Zeitschrift für Fleisch und Milchhygiene, x. p. 280.

cramps in the legs. The disease was traced to the use of milk from the same herd. This herd comprised 14 cows, one of which was proven to be afflicted with mastitis. Two persons working in the stable were sick with these same symptoms. The same forms of bacteria were found in the fæces of the sick persons that were found in the udder secretion of the diseased cow.

6. Moro [15] has reported the following case due to the use of the milk of a goat suffering with a necrotic inflammation of the udder: six persons who had taken the milk in coffee became very sick one to two hours afterward; they had chills, were nauseated and had headache; 11 hours later colic, vomiting and great thirst.

7. Lameris and van Harrevelt [16] mention an outbreak of diarrhœa among a number of persons in a hospital. The disease was traced with comparative certainty to the use of milk. This came from a herd in which several cases of streptococcus mastitis were found. The infection probably came from the use of milk from a cow that appeared to have recovered, but whose milk still contained streptococci. As the milk was used only after being boiled it was thought that the disease was really due to the presence of toxins, but it is very probable that streptococci may have lived through boiling of milk, as tubercle bacilli have, that is in the film, froth, scum or on the spoon, etc.

An observation by Edwards and Severn [17] seems to belong here. It concerns an epidemic of follicular inflammation of the tonsils which was traced to the milk, probably from one cow, which contained staphylococci and streptococci, which bacteria were also found in the coating of the throat of the affected persons.

[15] Archiv f. Wissensch. u. prakt. Tierheilkunde, 1886, p. 411.

[16] Zeit. f. Fleisch u. Milchhygiene, xi. p. 114.

[17] British Medical Journal, ii. 1897, p. 339.

In the literature there are reports of numerous similar epidemics of inflammation of the throat in man which had their origin in infection through milk, but there are no proofs that these were caused by cases of mastitis. They may have come from a later contamination of the milk with pathogenic bacteria.

[A large number of cases of this sort are recorded by Swithinbank and Newman in their "Bacteriology of Milk," published in 1903. L. P.]

Since cases of udder inflammation in which the secretion contains bacteria harmful to man cannot be differentiated by clinical means from the less dangerous, *the milk of every cow affected with mastitis should be regarded as injurious to health.* This applies not alone to the altered secretion, but also to the apparently normal milk from the parts of the udder not affected. The diseased secretion will always soil the udder and teats, and therefore there is no warranty that the bacteria in question do not fall into the milk when drawn from a healthy section of the udder. This is true especially when the improper practice is followed of milking the diseased secretion on the floor.

If a case of gangrenous mastitis appears in the herd, the affected animal must be removed from the stable, since it is possible that the milk will be contaminated with bacteria that are often especially virulent and that multiply very rapidly. Upon the occurrence of infectious inflammations of the udder in a milch herd it may be necessary to forbid the sale of milk that is not boiled. Milk from a herd affected with this disease should never be used as "nursery milk."

i. **Acute croupous and hemorrhagic enteritis.** Sometimes a virulent enteritis occurs among young cattle; it appears less often among mature cattle; it may appear as a sporadic disease or as a small epidemic. This dis-

ease is accompanied by fever and signs of great constitutional disturbance, and it quite often ends in death. The pathological changes have been studied comparatively little up to this time. It may, however, be stated that there is sometimes found a diffuse inflammatory hyperæmia in the mucous membrane of the whole small intestine, sometimes very extensive pseudo-membranes form a cast within the intestine, while in other cases swelling and hemorrhagic infiltration of Peyer's patches are found which, at the same time, may be ulcerated, or covered with crupo-diphtheritic exudate. The mesenteric glands, usually other glands, too, are swollen and more or less hyperæmic, or even hemorrhagic; the spleen may be enormously swollen. In some cases the lesions somewhat resemble typhoid fever in man, yet the disease is not identical with it.

The investigations that have been made by Jensen indicate that these forms of enteritis are, as a rule, caused by bacteria which belong to the hog cholera group and that are therefore closely related to the typhoid bacillus. The flesh of the infected animals may be most dangerous to health; not a few of the so-called "meat poisoning," epidemics have been traced directly to these forms of enteritis, and most of the bacteria isolated in meat poisoning cases belong to the hog cholera group.

It is not impossible that in virulent enteritis bacteria that have entered the blood may, now and then, be excreted in the milk as, for example, when there are slight hemorrhages in the udder tissue; doubtless, however, a serious contamination may occur during milking, for in this disease diarrhœa is a prominent symptom and the afflicted animals are much soiled by their faces.

A positive example of the transmission of such a form of enteritis to man through milk, has been given

by Follenius and Gaffky.[18] It is as follows: In the laboratory of hygiene at Giessen, two assistants and a servant became very ill after drinking raw milk which was proven to have come from a cow with hemorrhagic enteritis. The symptoms were headache, weakness and diarrhœa. In the servant, the disease seemed to resemble cholera, with the others it was more like typhoid fever. Gaffky isolated from the fæces of the sick persons, as well as from the fæces of the cow, a member of the colon group which grew rapidly and was very virulent. The organism was the same in all cases.

It is probable that a case of disease mentioned by Rehn,[19] was caused in a similar way. A child two and a quarter years old was attacked by a typhoid-like disease after drinking raw milk, *which was rich in colon bacilli.* He recovered in the course of five weeks. A sister somewhat older had a lighter attack.

As, doubtless, every case of such virulent enteritis of cattle offers opportunity for the infection of the milk with pathogenic bacteria, which apparently are virulent for man, every animal affected with a severe, bloody or febrile diarrhœa, should be removed from the stable at once. The contaminated part of the stable should be carefully cleansed and disinfected. If a number of cases of the disease occur, the sale of the milk of the whole herd must be prohibited, for a longer or shorter time.

In this connection, observations by A. Holst[20] concerning cases of poisoning through "pultost" (a kind of cheese) should be mentioned, since the bacillus found belongs to the same group, although it is not proven that its occurrence in the cheese was due to contamination with bacteria from cases of enteritis of cattle.

[18] Ref. in the Zeitsch. für Hygiene, III.

[19] Hygien. Rundschau, IV, No. 21.

[20] Zentralblat für Bact., XX, 1896.

Indigestion of cows very often leads to a lessening of milk secretion and, at the same time, to a change in its taste and composition. The milk may have a bitter or salty taste and appear to be thinner, is sometimes yellowish in color and coagulates very easily. When such changes are present, or when there is simply a disturbance of digestion, the milk should not be mixed with other milk designed for sale. The question here is not, however, one of the contaminating micro-organisms, nor does it relate strictly to the passage of a disease from cattle to man.

j. **"Calf cholera."** It is well known that under this common term are grouped infections of the intestines (usually caused by colon bacilli, less often by proteus forms) and umbilical infection, with or without local inflammation, (arthritis, pyæmic processes, bacteriæmia); the latter infection is sometimes caused by colon forms, sometimes by staphylococci and streptococci and, rarely, by necrosis bacilli or other bacteria.

An endemic outbreak of these infectious diseases signifies a great propagation of the causative bacteria in the cow stable and, therefore, it is most probable that the milk becomes infected while being drawn. There are no positive cases that prove that milk from a farm where calf cholera is prevalent, has caused disease of children or adults, but as no special attention has been given to this matter, it is quite natural that such cases as may occur are not fully understood. Milk from such a herd should be regarded as suspicious and its sale as "nursery milk" should not be allowed until conditions on the farm have been improved.

k. **Septic metritis.** In septic inflammation of the uterus, which is specially prevalent in herds where cows in calf are purchased from dealers, great quantities of ichorous exudate are secreted and expelled from the

vagina, and this exudate contains pathogenic bacteria (streptococci, staphylococci, colon forms, etc.) as well as bacteria of putrefaction (proteus varieties among them). During milking, some of this pathological material may fall directly into the milk and the udder, tail, thighs and flanks are usually so dirty that contamination of the milk is scarcely avoidable. There are no definite observations of disease that has been caused in man through the milk of such animals, but since these organisms are known to be harmful there can be no doubt that the milk may be injurious to health; therefore, its use should not be permitted under any conditions. Since it is readily possible that the cows standing beside the affected animals are contaminated by the excretions from the uterus, sick animals should not be allowed to remain in the stable occupied by the milk producing herd.

The same applies to cows which *retain the afterbirth*, but without suffering from septic metritis. The danger of contamination with pathogenic bacteria in this case is not great but the milk may be contaminated very easily by the entrance into it of the bacteria of putrefaction that are present in the purulent discharges. Moreover, the milk—even that of healthy animals—may absorb foul odors during milking, odors which are often very pronounced throughout the whole stable where such an animal is stalled; or the odor of carbolic acid or creolin used for treating the animal may enter the milk. Hence, such cows should be taken to an isolated part of the stable where other cows cannot come in contact with them and their milk should, under no circumstances, be added to the market milk.

l. **Suppurative processes.** What has been said of septic metritis applies, essentially, to diffuse cellulitis and extensive suppurating sores. When animals with such conditions are in the stable, there is great danger

that the milk may be infected with bacteria of suppuration, among which streptococci are able to cause enteritis in man. With wounds and ulcerations of the teats (pox, gangrenous buckwheat eruption, etc.), the danger is present and the milk of such cows should, at least, not be used for nursery milk. If there are single small sores that no longer suppurate, the milk may be sold, provided the teats are carefully washed before milking.

m. **Other infectious diseases.** The secretory function of the milk glands is affected to no small degree in many severe infectious diseases. This is shown principally by the diminished quantity of milk but often, at the same time, by changes in its composition. In this way the milk may acquire an unpleasant or salty taste; its layer of cream has often a dirty color and, when it is boiled, little lumps separate due to the increased quantity of albumin or globulin. It is probable that under these conditions abnormal products of metabolism and, now and then, pathogenic bacteria find their way into the milk; therefore, milk should not be used in severe cases of fever, as rinderpest, malignant catarrhal fever, croup, malignant broncho-pneumonia, pyæmic and septicæmic processes, etc.

n. **Milk sickness.** A curious disease called "milk sickness" is found in the central part of the United States; it was formerly confused with anthrax, and has occurred as an epidemic among animals and man but seems to disappear with improved cultivation. According to the reports of Dr. Kimmell the disease occurs among horses and ruminants, when they are pastured in certain places. After a period of incubation, violent trembling and great restlessness appear which increase during the succeeding days. The animal may fall and die suddenly but often it lies for several days in a paralyzed, half dead condition. Through the ingestion of

meat, milk and dairy products, the disease is communicable to man. It may develop mildly with severe vomiting and difficult breathing as the prominent symptoms, or, on the other hand, it may end in death, preceded by subnormal temperature, paralysis of a great part of the body and progressive dyspnœa. Death approaches imperceptibly and without the supervention of rigor mortis. This mysterious disease, which was formerly attributed to poisonous plants eaten by the cattle with their food and whose toxic principles were supposed to be secreted in the milk, is probably, according to the preceding, an infectious disease.

V. CONTAMINATION WITH ORGANISMS OF SPECIFIC DISEASES OF MAN

Milk may be contaminated with specific organisms from persons suffering with infectious diseases. Such contamination may take place during milking, during its handling on the farm or, later, while it is being handled or stored in the dairy or market-place. Sometimes this occurs from sick persons coming directly into contact with the milk, sometimes it occurs in an indirect way. The method of contamination differs in respect to different diseases, since infectious material may come not only directly or indirectly from persons but may also come from the water used for cleansing the milk vessels.

In the literature of recent years, there are numerous reports of very significant epidemics supposed to be due to infection carried by milk. Such " milk epidemics " are especially frequent in England and America and this may, no doubt, be accounted for by the fact that it is not so customary in England and America to boil milk as it is, for example, in Denmark and Germany. Most of the epidemics relate to typhoid fever, diphtheria and scarlet fever; but cholera and several other diseases may

be spread by means of milk. In some cases, no doubt, epidemics have wrongly been ascribed to the use of milk, for their origin might be explained in another way, but a very great number of cases remain wherein the responsibility of milk as a distributor of contagion cannot be doubted.

[In most cases, the conclusion that a given outbreak of disease is caused by the use of infected milk does not rest on the evidence of the discovery of the specific organism in the milk, but on the manner in which the outbreak occurs and upon the various attendant circumstances. For this there are two reasons; first, none of the specific germs may be present in the drop or two subjected to examination, even though they are relatively numerous in the whole supply, for such organisms are not in solution and are not evenly distributed and, second, infectious diseases do not occur until after a certain period of incubation, and when this time has elapsed the milk that carried the specific organisms is no longer in existence. But the evidence of the transfer of such diseases by milk is none the less convincing. It is as clear, for example, as the evidence that typhoid fever is carried by contaminated water, and this evidence is regarded as sufficient to justify the expenditure by cities of vast sums to secure pure water.

Milk epidemics are often characterized, according to the observations of Swithinbank and Newman [21] by the following features:

1. Special incidences of disease, as among the customers of a certain milkman; in families using the greatest quantities of milk; among persons who drink most milk and, for this reason, among women and children.

2. A relatively short period of incubation.

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[21] The Bacteriology of Milk, London, 1903.

3. Sudden onset and rapid decline of the outbreak.

4. Certain clinical characteristics of the milk-borne disease, especially a somewhat milder form of disease than is customary.

5. A lower mortality rate than when the disease is transmitted by other means, as shown by the following table:

Disease	Mortality Percentages	
	Milk-Borne Outbreaks	Not Milk-Borne
Scarlet fever.....	12.0	16.2
Typhoid fever.....	11.0	17.4
Diphtheria.....	18.9	30.3

The above table is made by Swithinbank and Newman (whose chapters on this subject should be read) from a study of many thousands of cases of milk-borne disease. It should be stated that the mortality percentages in the first column are actual, and taken from the records, while those of the second column are based on estimates from other writers. L.P.]

a. **Typhoid fever.** During recent years, especially, there have been numerous reports from city and country, of typhoid epidemics which have been traced to contamination of the milk by typhoid bacilli, and to the dissemination of disease through such milk. At first, the correctness of the observations was doubted, since it was not possible to find the typhoid bacillus in milk, but recently the observations have so increased in number and accuracy that it is not to be denied that *the principal means by which typhoid fever is distributed in places where there is a safe and hygienic water supply, is through the milk.* Although it cannot be said that typhoid fever is especially prevalent in Denmark, yet a

number of epidemics during recent years, may be pointed out that can be traced with more or less certainty to infection through milk, or with which milk was concerned in the great spread of the contagion. Dr. Caröe [22] has reported about 90 large and small typhoid epidemics which occurred outside of Copenhagen during the period from 1878–96 and which probably were due to infection from milk, also 5 milk epidemics which occurred in Copenhagen during the years 1879–1895. In 1900, no less than 3 milk epidemics occurred in Copenhagen, and it does not appear that these were related to each other. The sanitary inspector, A. Ulrik,[23] made a detailed report on these outbreaks, and since they show very characteristically the conditions that occur in milk epidemics, they are cited as examples.

In the first epidemic, the cases were grouped about a city milch herd and the two sales places connected with it. Some cases of typhoid appeared in this quarter of the city in August, but the origin of these was not perfectly clear. At this time, a saleswoman in charge of one of the milk shops became ill of typhoid fever and was taken to the hospital. It was discovered that she had suffered with severe diarrhœa for about fourteen days but she had not been under the physician's care until high fever developed. By degrees, 35 cases in all broke out, among them the woman in charge of the other milk shop and these cases were, in part, traced directly to infective milk; in part they must have originated from contagion carried from one person to another. It was found during the time that the disease prevailed that the milk had twice been infective—at the beginning and in the middle of August—but it was not possible to prove the exact channel through which bacilli entered.

[22] Tidsskrift for Sundhespleje, VI, 1898.

[23] Tiddskrift for Sundhespleje, VIII, 1901.

The state of health of the herd and the condition of cleanliness of the premises aroused no suspicion. After cleansing and disinfecting and after discontinuing the business for a short period, the epidemic ceased at once, although a few individual cases still occurred that were caused by infection that had taken place earlier.

The milk of these same shops was infected anew in the middle of October, probably by a girl who was believed to have become infected during a stay in a place near Copenhagen. Shortly afterward, the two sons of the herdsman were infected by the milk, and later three other persons. By means of a temporary prohibition of the sale of raw milk and raw cream from the herd and by thorough cleansing, the epidemic was checked.

The third epidemic was of greater extent. In the middle of November a number of typhoid cases were found in a certain section of the city and suspicion soon fell on a certain milk shop. The further development of the epidemic, during which the shopkeeper became ill, confirmed these suspicions. Altogether, 71 persons were infected directly or indirectly through the milk, which must have been most contaminated from October 26th to November 1st, judging from the times of appearance of disease and the number of persons affected. Despite the investigation which was instituted, the ultimate origin of the infection was not discovered.

H. Möller has observed and described as follows an epidemic caused by milk from a coöperative dairy, which is rather characteristic:[24] Seven farms supported a coöperative dairy. A case of typhoid fever occurred on one of the farms; the dairy continued to receive the milk but did not boil the skim milk that was returned. With brief intermissions, 40 persons, altogether, became in-

[24] Ugeskrift for Laeger, 1890, p. 128.

fected with typhoid fever on the dairy farm first infected, on the farm upon which the creamery was situated and on 4 other farms, only one farm remaining exempt. Through contagion, the disease was carried from these farms to 7 other families and 14 more persons became affected.

Hart's and Freeman's collections of the milk epidemics in the literature gave an idea of the importance of this method of transmission of typhoid fever. Hart collected the established milk epidemics from 1857 81 and found accounts of 51, with 3500 cases of the disease and 350 deaths, while Freeman found 53 epidemics from 1880 96. The number of milk epidemics observed since then is proportionately greater, no doubt because this means of transmission is better known and, therefore, is more frequently recognized than before.

While in the case of some epidemics it is quite easy to prove that the infection of the milk came from a sick person working with the milk, in other cases everything points to the producing farm as the seat of infection, but may not reveal the ultimate origin of the contagion. In such cases attempts have been made to trace the infection to a disease of the cows, but without sound basis, for no instance is known wherein domestic animals have suffered from any disease caused by the typhoid bacillus.

From our knowledge of the epidemiology of typhoid fever, it may be said with assurance that milk may be infected with typhoid bacilli through the addition of water (in washing the vessels or through adulteration with water) or by bacteria from patients or convalescents.

It is a well known fact that many epidemics of this disease have been traced to infection from impure drinking water, and it is self evident that milk, which is favor-

able to the growth of typhoid bacilli, may be infected in this way. Water from open or thin walled springs or wells may be directly infected by the entrance of water which has been contaminated by the excretions of the sick. [All surface streams are liable to become contaminated either directly or indirectly, through carelessness or imperfect drainage systems.

Typhoid bacilli may be blown about in dust, carried on the boots of persons who walk over infected surfaces and they may also be carried by flies, as was abundantly proven during the Spanish-American and the South African wars. Cloths used for washing milk cans may carry this infection. In one instance, in Philadelphia, it was found that a small milk dealer was in the habit of washing his milk bottles in the family wash tub. Milk has become contaminated during cooling, either by a leak in the tubular cooler or by the entrance of water into a submerged can. L. P.]

Concerning direct or indirect infection from sick persons or convalescents, emphasis should be laid upon the fact that the disease often runs so light a course that the diagnosis of typhoid fever is not established; further, that fæces, and often urine, contain bacilli in great number and that convalescents often have bacteriurea for months after typhoid fever and daily excrete numberless bacilli with the urine. Neufeld [25] has collected some reports on this subject: of 210 typhoid patients not less than 45 (more than 20%) excreted bacilli with the urine, and Petruschky [26] found that the number of bacilli in the urine exceeded 170,000,000 per c.c. It will be evident to every one who is familiar with existing conditions and customs, especially in the country, that under these circumstances no extreme or unusual carelessness or

[25] Deutches med. Wochenschr., 1890, p. 824.

[26] Zentralbl. f. Bakteriologie, XXIII, 1898, No. 14.

accident is necessary to afford an indirect or direct means of carrying typhoid bacilli into the water or milk.

The typhoid bacillus can multiply rapidly in milk and greatly increase in number in the course of a short time, it resists the commencement of acid formation but is partly checked and killed by great acidity; yet it is not certainly killed by the degree of scouring to which cream is subjected before churning. Bolley and Field have found that typhoid bacilli will live at least ten days in butter [and Bruck has shown that they were virulent after 27 days]. Hence, not only milk and cream but also buttermilk (epidemic in Hamburg; Fränkel and Köster), newly made butter and fresh cheese may be bearers of virulent typhoid bacilli. The typhoid bacillus is destroyed by pasteurization at 80° C. (176° F.) and heating for a few minutes at 70° to 75° C. (158° to 167° F.) will kill it. Care must be taken to heat the whole volume of milk to this temperature. (See "Pasteurization.")

In pure culture, the typhoid bacillus does not change the appearance of milk and alters its reaction but little. It is very difficult to detect it in milk, as it is in drinking water, for its colonies in gelatin are very similar to those of the colon bacilli. To detect it, the milk must be sown in the usual method in gelatin plates and then as great a number as possible of suspicious colonies isolated. These are then implanted in fermentation bulbs in bouillon, some of which contain grape sugar and some sugar of milk. Those forms which cause an acid reaction in the milk sugar bouillon or those which ferment the grape sugar with the formation of gas or which do not change the reaction of the grape sugar bouillon are to be rejected. Only those cultures which give a strong acid reaction without producing gas in the grape sugar bouillon, are really suspicious and these must be sub-

jected to a far more searching examination before they can be identified as typhoid bacilli.[27] It is unnecessary to pursue this subject further, since the demonstration of the typhoid bacillus in market milk is not, as yet, a practicable procedure in milk inspection.

Jensen's investigations have shown that there are several kinds of typhoid bacilli, distinguished from each other by a somewhat different fermentative power. It appears to be possible that by means of cultures from different patients one may determine what cases of typhoid belong to one and the same epidemic.

b. **Diphtheria.** Diphtheria not infrequently appears to be spread by milk from milk shops or by that delivered from coöperative dairies, but less frequently than typhoid fever.

N. Flindt[28] has given a detailed account of such an epidemic in the neighborhood of Holbeak in which the disease was being spread for a long time by milk from a coöperative dairy. He states: The epidemic occurred in June, 1889, and soon became violent. Fifty-one persons were sick at the end of the month, 16 cases occurred the following month and in August and September 6 more; 3 patients died. Everything tended to prove that milk delivered from the coöperative dairy had contained the contagion and this belief was strengthened by the fact that two persons from the dairy were affected. The exact mode of entrance of the infectious material into the milk was not traced. The case is remarkable in that the milk appears to have been contaminated for quite a long period.

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[27] C. O. Jensen: On Vanskelighederne ved Typhusbacillens Diagnose og om Racer af Typhusbacillen. (On the Difficulties of Diagnosing Typhoid bacilli and on the Races of Typhoid bacilli) Hospitalstidende, 1901, p. 1193.

[28] Ugeskrift for Laeger, 1890, p. 405.

A large epidemic of diphtheria[29] which broke out among the inhabitants of the villages along the coast north of Copenhagen, in 1881, offered conditions of propagation which strongly signified that milk was the means of spreading the contagion.

In 1893 a small epidemic was noted in Lund, Sweden, when eight persons in different families were sick with diphtheria. These cases were traced to the use of milk from a farm near Lund which was infected with diphtheria.[30]

Quite an extended epidemic occurred in 1886 in Frimley, England; in the course of a few days 70 cases of diphtheria occurred, distributed in more than 30 families, 15 cases being fatal. All the sick had received milk from the same dairy. Not one case of diphtheria occurred during this time among those using milk from other dairies.[31]

[The medical literature of recent years contains many reports of milk-borne outbreaks of diphtheria, a number of which are gathered and summarized by Swithinbank and Newman.[32] The following case, cited in their summary, is instructive. At Ashtabula, Ohio, 100 persons became affected with diphtheria in December, 1894. The houses in which the disease occurred were widely separated but milk was taken at all of them from the same dairyman. On the farm of this dairyman, a workman had a very sore throat, probably diphtheritic. This person had assisted in the work of the dairy while suffering acutely from sore throat. Of 44 households investigated, it was found that 32 had received

[29] Ugeskrift for Laeger, 1881.

[30] Hospitalstidende, 1893.

[31] Ref. in Milchzeitung, 1886, p. 835.

[32] Bacteriology of Milk.

milk directly from this sick person; the other 12 had received milk from the same dairy but it had been delivered by another man. In this outbreak there were 24 deaths. L.P.] A great many other reported cases might be quoted.

As yet the diphtheria bacillus has rarely been isolated from market milk but, notwithstanding this, there can be no doubt of its occurrence in milk and that it may thus cause epidemics like those mentioned above. The bacillus must come directly or indirectly from the oral cavity of people who are or have been recently attacked by diphtheria. Just as the typhoid bacillus is maintained in many cases in the urine of convalescents, it is also very common for diphtheria bacilli to retain life for months, even for a whole year, in the oral cavity and on the mucous membrane of the nose in persons who have been affected, but who have entirely recovered from the disease. It is on this account that it was possible in only a few epidemics of milk-borne diphtheria to discover the original source of infection and it is difficult, not to say impossible, to wholly guard against the occasional infection of milk by diphtheria bacilli. Fortunately, these bacilli are frequently of low virulence.

The opinion, that was held formerly by some, that diphtheria in man could come from a disease of milch cows, is entirely erroneous.

It has been stated that diphtheria bacilli grow readily in raw milk and that they thrive less well in boiled milk (Schottelius); but from the experiments made by Meyer, it appears that diphtheria bacilli act as other bacilli; that is, that they are checked by the germicidal power of fresh raw milk and grow best in boiled milk.

Diphtheria bacilli withstand acidity and may therefore be present in the different dairy products, but the infectivity of the latter has not yet been determined.

It is certainly very difficult to prove the presence of diphtheria bacilli in market milk because even if the milk has been the cause of the epidemic, they are present in only very small quantity and, usually, but for a limited time. If one wishes to experiment in this direction the best method of proceeding is to make a culture on blood serum (Löffler's) in a manner similar to that employed in the examination of the throat of a diphtheritic patient. If the culture tubes are brought to body heat for 24 hours, the conditions will be more favorable for the increase of the diphtheria bacilli than for the greater number of milk bacteria. One must then make a careful study of the colonies that have developed.

c. **Scarlet fever.** Reports of scarlet fever epidemics that are presumably to be attributed to the spread of infection through the milk, come chiefly from England and America. The infectious material must come from affected persons and may enter the milk directly through their contact with it when it is being drawn, in the sales-places, etc., or it may reach the milk in an indirect way. Since the organism of this disease is unknown, it is difficult to form a well founded opinion concerning these possibilities, and one cannot ascertain whether there is an increase of the infectious material in milk.

About 18 years ago some scarlet fever epidemics aroused great attention in England because it was thought that, without doubt, they could be traced to an infection through milk and to a peculiar new eruptive disease upon the teats and udders of cows. From the evidence that is now available, one is justified in regarding it as established that the outbreaks of scarlet fever referred to had no relation to the disease of cows, which was in reality only a somewhat unusual form of cow pox.

Malet [33] cites an example of a milk epidemic wherein from August 21st to the 2d of September, 18 persons belonging to 11 households were attacked with scarlet fever after drinking milk from a farm where there was a scarlet fever patient.

[The cases next following are selected from among those cited by Swithinbank and Newman.[34]

Buffalo, New York (reported by Wende). "Two outbreaks of scarlet fever occurring in 1899 in Buffalo were traced to an infected milk supply. The first outbreak was that of 57 children, the second was less severe and numbered only 20 cases. The channel of infection was well traced out in the former, and it was found that on the implicated dairy premises there were two cases of desquamating scarlet fever. One was a child, aged 9, the other a young man aged 19 who did the milking and in other ways assisted in the dairy during his illness. The 57 cases were almost simultaneous in occurrence, and the severity of the attack appeared to depend upon the quantity of the implicated milk consumed."

London, 1901. The total number of cases was 293, all resulting from one polluted milk source. "The outbreak occurred on the delivery course of a certain contractor in London. He obtained milk from 38 farms. On one of these farms there were four cases of scarlet fever, the farmer, his wife, son and daughter. The cows were healthy." The cases were widely scattered in London but were all directly traceable to milk from the implicated farm. "The large number of adults attacked differentiated this outbreak from those of ordinary type. After the regular distribution had been stopped the con-

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[33] Reference in Recueil de méd. vétr., 1895.

[34] Bacteriology of Milk. For original references to cases cited, see this work.

tractor then sent his milk to other consumers, who then contracted scarlet fever."

Beverly and Salem, Massachusetts, 1901. The number of cases was 60, all resulting from one polluted source. "The dairyman in this outbreak produced 5 cans of milk daily and obtained 14 other cans from 3 neighbors. On one of these 3 farms, 3 children had been ill; a girl of 16 had sore throat, another girl of 12 and a boy of 14 followed a few days later with a similar affection, namely, swelling of the glands in the neck, and general malaise. One of them had a slight rash. After the recovery from acute condition they assisted in handling the milk. The outbreak was very sudden, and promptly declined from a time dating a few days after the milk supply from the farm was stopped. The fatality was high, as many as 11 deaths occurring. The distribution of the cases of scarlet fever was localized to the distribution of the milk in question." L. P.]

d. **Asiatic cholera.** From what we now know of the epidemiology of cholera it cannot be doubted that the spread of the germs of cholera is due chiefly to drinking water; nevertheless the possibility of its spread through milk and other foods cannot be left out of consideration. Examples of transmission through milk are certainly not numerous; one of the best established is the following reported by Simpson: On board a ship in the harbor of Calcutta, 10 persons fell victims to cholera after drinking milk sold by a native. Four patients died, 5 others were seriously ill, and one who drank but little of the milk was slightly affected. It was learned that the milk had been diluted with water from a tank into which the excrement of a cholera patient had been thrown a few days before. Among those who did not drink the milk there was no illness.

Simpson was able also to trace a small cholera epi-

demic in a prison in Calcutta, with considerable certainty, to the distribution of the cholera bacilli through the milk, and it was probable that the milk was already infected before delivery. Gaffky also reported an epidemic caused by infection through milk.

In quite fresh milk, cholera bacilli appear to succumb readily to its bactericidal action, but they increase rapidly in older milk but are again checked and, at last, killed, as the acidity increases.

e. **Tuberculosis.** Tubercle bacilli may enter milk not only from tuberculous cows and infected stables but also, without doubt, from tuberculous people. Of course there is no definite illustration—for obvious reasons—of transmission of tuberculosis in this way; but if one considers what a quantity of tubercle bacilli may be excreted daily by a consumptive, the possibility of such transmission can scarcely be disputed, although the danger is considerably lessened by the fact that the number of tubercle bacilli will not increase while the milk is kept. It is justifiable, therefore, to forbid tuberculous people working with market milk.

f. **Other diseases.** It is stated in text books that there are instances of the transmission of syphilis, and there are reports in English journals of epidemics of sore throat and of erysipelas which are said to have come from infection through milk. In these latter cases, however, it is doubtful if the infectious material came directly from sick people, for the microbes concerned (chiefly streptococci) may gain access to milk from other sources.

[As illustrations of such outbreaks of sore throat, the three following cases are taken from among those summarized by Swithinbank and Newman.[35]

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[35] Bacteriology of Milk.

In Anglesey, in 1897, 15 people who took milk of one dairy, became affected at about the same time with sore throat. Several persons in the affected families who consumed milk from the same source but in a boiled state escaped the sore throat, the chief evidence of which was tonsilitis. The bacteriological examination of the milk revealed the presence of *Streptococcus pyogenes* and *Staphylococcus pyogenes*, but no *Bacterium diphtheriæ*. Bacteriological examination of the patients' throats yielded precisely similar results.

"In May, 1902, an outbreak occurred in Lincoln, affecting a large number of persons. Dr. Brook had seventy-five cases in his own practice. The chief symptoms were erythema of the face, and sore throat. In many cases a drab colored fur covered the tonsils. A roseolous, papular eruption, in some cases appearing to be urticarial, occurred in two-thirds of the cases. There was no marked fever, except in cases having complications. The pulse rate was not increased, and no albuminuria occurred. The onset was sudden, and in no case out of the seventy-five investigated by Dr. Brook was infection communicated to others by contact. Nearly all of the patients were adults, and well advanced in years. The complication most commonly met with was swelling and tenderness of the cervical glands. With one doubtful exception, all the patients had had milk from the same dairy. Boiling the milk appeared to prevent persons from taking the complaint. The poison seemed to be present particularly in the cream. The differences between the disease and scarlet fever were very marked.

"A sudden outbreak of a severe form of 'septic sore throat' occurred at Bedford at the end of June, 1902. On 27th June, the first case occurred; on 29th June, 4 cases occurred; 30th June, 15 cases occurred; 1st

July, 13 cases; 2nd July, 3 cases; 3rd July, 2 cases; and 4th July to 8th July, 4 cases—making a total of 42 cases in 22 families. The symptoms included redness, swelling of the throat, fauces, palate, and uvula, with numerous spots, patches of exudation, and in some cases ulcers. The general symptoms consisted of severe headaches, giddiness, backache, and pains in the limbs, very much like an attack of influenza. The temperature was about 102° to 103° F., but in a few cases was higher. In some cases there was gastric and intestinal disturbance. Great weakness was also present. In every case the milk supply was obtained from the same dairy. On Sunday, 30th June, many persons consumed cream with fruit, and these included nearly all the worst cases. In some families children who drank boiled milk escaped, whilst parents who consumed unboiled milk or cream were attacked. One man took cream in the form of ice-cream, and had a severe attack.''

It must, however, be regarded as possible that these cases of sore throat were caused not by contamination of the milk from a human source but to the presence of organisms of suppuration eliminated by cows with diseased udders. L. P.]

The transmission of measles, small-pox, pest, dysentery, or cerebro-spinal meningitis by milk has not been observed, but the possibility of such transmission can scarcely be doubted.

VI. CONTAMINATION WITH OTHER BACTERIA

Milk becomes infected with bacteria during the act of milking. These contaminating organisms come partly from the teat canal, partly from dirt, hairs, and dandruff on the skin of the cow, partly from the hands and clothing of the milkers, partly from the dust of the stable. Still more are added when the milk is collected and

stored in unsterilized vessels or when it is exposed to the air. It is evident that the number of bacteria found in freshly drawn milk varies greatly according to the conditions of cleanliness of the stable and the cows, and as to the cleanliness and carefulness observed during milking.

Freshly drawn milk possesses a certain bactericidal action which, however, does not seem to affect all forms of bacteria. The number of living bacteria in milk may be lessened appreciably in the course of a few hours as a result of this activity, but the action does not last and, under appropriate temperature conditions, bacteria soon begin to increase and their number, at times, becomes enormous. The rapidity with which the bacteria increase after milking is dependent entirely upon the temperature at which the milk is kept.

If the milk is cooled immediately after being drawn and is kept at a temperature not higher than 10° C. (50 F.) there is no material increase of bacteria during the first 24 to 36 hours; even at 14° to 15 C. (57.2 to 59 F.) the increase is relatively slight. But as the temperature rises, the number of bacteria increases rapidly and bacteria are very numerous in milk that has stood at 20 to 25° C. (68 to 77 F.) for 12 hours.

In order to illustrate the importance of cleanliness in the stable and during milking, the following figures determined by Grotenfeld may be of use. In one c.c. of milk from cows particularly well cared for, he found 106 bacteria, while the freshly drawn milk of cows in a dirty stable contained 617,000 bacteria per c.c. Therefore, one cannot generalize as to the number of bacteria in freshly drawn milk, but milk from well-cared-for and carefully milked cows will, as a rule, contain hardly more than 1000 to 6000 bacteria per c.c. The following results show the potent effect of cold in checking the increase of bac-

teria. The milk used contained about 9300 bacteria in one c.c. and was kept at 15°, 25°, and 35° C.:

	At 15° C. (59° F.)	At 25° C. (77° F.)	At 35° C. (95° F.)
Beginning of the test.	9,300	9,300	9,300
After 3 hours	10,000	18,000	30,000
After 6 hours	25,000	172,000	12,000,000
After 9 hours	46,000	1,000,000	35,280,000
After 24 hours	5,700,000	50,000,000	577,500,000

At the low temperature, it is seen that the increase is at first very slight. Moore found that the number of bacteria in milk kept at 21° C. (70° F.) did not increase during the first 6 to 9 hours but then increased rapidly; he also found that in the course of from 36 to 48 hours, no appreciable increase in the number took place, if the temperature did not rise above 12° to 13° C. (53.6° to 55.4° F.) and that a still lower temperature, as 4° to 5° C. (39.2° to 41° F.), could prevent the increase of bacteria for a longer period. Meyer found, through experiments carried on in Jensen's laboratory, that cooling the milk to 10° to 12° C. (50° to 53.6° F.) checks the growth of bacteria for a long time.

It is evident, from all of this, that the quick and permanent cooling of the milk to 10° to 12° C. (50° to 53.6° F.) is most important in preserving it.

Of course the number of bacteria in market milk varies greatly according to its age and care and to the temperature of the air. Experience gained in most of the larger cities shows the bacterial content of market milk to be seldom below 50,000 to 100,000 per c.c. but it is often greater, varying between 1,000,000 to 30,000,000; indeed, not infrequently, even from 100,000,000 to 150,000,000 have been found. And such milk may not be noticeably tainted.

If the question be asked: What is the sanitary significance of the existence of this mass of bacteria? we must consider the changes which bacteria in pure culture may cause in milk, and which were mentioned above, for it is evident that these same changes occur, although often very much less clearly marked, in market milk rich in bacteria. When milk is kept a long time it may become altered in one of several ways, of which the following are the most common:

1. The well known coagulation (curdling), following the formation of acid, is the most frequent.

2. Less often, a more or less disagreeable (putrid) odor and taste occur without much acid formation and without coagulation.

3. Still less frequently, the milk becomes slimy or "stringy," either without souring, or accompanying the process of souring.

Sour milk. It is known that sour milk has no harmful effect on healthy people. But it is different with those suffering with catarrh of the stomach, and with small children. In these cases a degree of acidity not betrayed by coagulation or appreciable sour taste apparently may cause vomiting and indigestion, possibly because the numerous lactic acid bacteria rapidly increase with the warming of the milk in the stomach, and cause coagulation before the gastric juice can check their growth. Milk in which the lactic acid fermentation is so far advanced that it will not stand boiling, or the taste of which is slightly sour, must therefore be regarded as unfit for food for small children. The number of bacteria in milk does not give us a safe criterion for judging it in this connection, but the degree of acidity furnishes a reliable guide. (See below.)

Putrid milk. Even though the taste is not yet decidedly foul, but is only bitter (formation of peptone)

nausea and vomiting may be caused, even in adults, and there are many instances of the poisoning of large numbers of people by such milk. This alteration is most frequently observed in summer when the milk is not properly cooled, and occurs especially in milk that has been warmed or even boiled for a short time [pasteurized], without sufficient cooling afterward.

Slimy milk. According to information at hand, the slimy change seems to have no harmful effect, although it may make the milk most unappetizing. In Sweden, however, this change is produced and "langmjölk" is prepared for food, as sour milk (curds and whey) is prepared in other countries. Milk that is inclined to the slimy change should not, at any rate, be fed to small children.

Some bacteria that occur in milk but which, on account of their properties or small number, do not have any noticeable effect upon the appearance or changes of the milk, may still be harmful. These are sporulating forms, as the hay bacilli or members of the group of butyric acid bacilli, which may break up the casein with the formation of albumoses, peptones and amid- and ammonia compounds. Sometimes there are bacteria which generate special poisons that go into solution in the milk or that remain attached to the bacteria cells. Little is known of these forms, although the opinion has been frequently expressed that these very bacteria play an important part in the etiology of diarrhœa in children. Finally, there may be bacteria which are pathogenic for animals and for man and that are capable of causing inflammation. Such bacteria are very common in market milk. In the examination of 56 samples of market milk in Berlin, Beck found streptococci in 34, which caused fatal enteritis when fed to rabbits and guinea pigs. In injecting milk in the abdominal cavity of rab-

bits (in order to test it for tubercle bacilli) Friis discovered that 15 of the 28 samples contained bacteria which caused either peritonitis or abscesses or pyæmia. Guinea pigs were generally useless for his experiments because they all died of peritonitis. Similar results have been obtained by many others.

The forms of bacteria considered in this connection are chiefly streptococci, staphylococci and members of the colon group, some of which are generally present, although, perhaps, in quite small amounts, in market milk; besides these, there are still many other kinds, some of them occurring regularly, in small numbers, and some are only met with now and then. Where do these bacteria come from? Primarily from the dirt that gets into the milk when it is drawn, it is a well-known fact that the excrement contains numerous, and sometimes pathogenic, bacteria. They may also come from cases of mastitis and metritis in the stable; moreover these forms of bacteria are widespread and probably they very often occur in cow stables, as is shown by the frequent occurrence of calf cholera. "Calf cholera" is a common name for a group of fatal diseases of new-born calves among which the most usual forms are navel infection (most frequently caused by streptococci, colon bacilli and pseudo-colon bacilli) and diarrhœa or dysentery of calves (in most cases caused by colon bacilli).

It does not follow that all milk containing streptococci or the other bacteria referred to above is harmful or dangerous. But if these are present in large numbers, they make the milk suspicious and there are many evidences that such milk has been most injurious. It is highly probable that a very great part of the gastro-enteritis, so harmful to small children, is traceable directly to these bacteria. The fact that the mortality among small children in general has decreased to a great

extent where the milk is bacteriologically clean or has been sterilized according to Soxhlet's method, is one of the arguments in favor of this view. Heubner is of the opinion that infant mortality has been diminished in this way to the extent of 27 per cent.

In order to prevent too great contamination by such bacteria—it is difficult to wholly exclude them—there is no other way than strictly to guard the health of the herds, as well as the cleanliness of the stable [of the utensils and receptacles] and of the attendants. The eventual danger may be partly removed by pasteurizing or boiling the milk.

VII. ADMIXTURE OF DIRT

As has already been stated, it is customary for milk to become more or less contaminated with particles of dirt and their adherent bacteria during milking. The dirt consists, principally, of bits of manure and, besides this, hairs, dandruff, particles of food, earth and dust.

Usually, after milking each cow, the milk is passed through a strainer which retains particles of dirt; but if the strainer is not cleaned very frequently, the particles of dung and dirt are softened in the milk, bacteria are washed through and substances that carry abnormal odors and tastes are set free in the milk. By straining, then, one accomplishes only the removal of the larger and more solid particles of dirt that are quite harmless in themselves, such as hairs, cellulose, sand, etc.

When unclean milk is permitted to stand, a distinct sediment is formed and its presence signifies lack of cleanliness in respect to production.

The importance of dirt contamination is due chiefly to the addition of bacteria with the dirt and to the solution of fæcal matter; the visible dirt is important only as it makes the milk unappetizing. It follows that a

greater or less dirt content has a great influence upon the healthfulness and keeping quality of the milk; this is emphasized by a study of the bacterial content of cow dung. Wüthrich and Freudenreich found this to vary according to the kind of feed; the bacteria in the dung of cows fed with hay appeared to be most numerous; 1 gramme of such excrement contained 375,000,000 bacteria.

Of course the quantity of dirt in market milk differs very greatly. An investigation in Hamburg showed that the quantity varied from 0.0 to 183.5 milligrams per liter; on the average, there were 13.5 milligrams of dry dirt in a liter of milk. In other experiments, Schmelk in Christiania found an average of 11 milligrams in a liter, von Hellens (Helsingfors) found only 1.79; in Berlin, Renk showed the average to be 10.3; in Halle, 14.92; in Leipsig, 3.8 and in Munich, 9.0. The maximum quantity in each case was much greater than the averages mentioned, although it never reached the maximum for Hamburg milk.

In Dresden the standard regarding market milk states that it must not contain more than 8 milligrams of dirt per liter.

In Denmark there are no general regulations concerning the dirt content of milk;[36] there, too, it varies considerably, it is great in the milk from distillery fed herds and less in milk delivered by the large companies.

[36] In 1895, the Copenhagen health commission had 39 samples of milk tested for dirt, which was found in small quantity, varying between 1 and 13 milligrams per liter.

PART IV.

PASTEURIZATION AND STERILIZATION

In the household, milk is boiled to make it keep longer and this process serves also to kill any pathogenic bacteria that may be present. Little by little, the public has learned that milk often contains disease producing germs and that small children are especially exposed to their harmful effects, so the custom has become more or less general of sterilizing milk intended for infants. Quite naturally, the idea developed to sterilize market milk, by heating before it was offered for sale. By this means, the following desired results have been obtained: the milk keeps for a longer time, it loses its capacity for infection, and the annoying process of sterilization in the home is avoided. In most large cities there are one or more companies engaged in the sale of sterilized or pasteurized milk.

The difference between pasteurization and sterilization consists, essentially, in the greater degree of heat applied during the latter process.

I. PASTEURIZATION

By pasteurizing a fluid is generally understood heating it to a certain temperature which is sufficient to increase its keeping qualities. It is sometimes used to indicate heating to 50° to 60° C. (122° to 140° F.) and sometimes to the use of a higher temperature. In reference to milk and dairy products, the term "pasteurization" is used in a more definite sense. In butter-

making pasteurization is understood to mean a brief heating of the cream and whole milk to 80° to 85° C. (176 to 185 F.), the purpose of which is to kill most of the existing bacteria, in order to prevent those fermentations of the cream which might cause the butter to be of inferior quality. At the same time, pathogenic micro-organisms (particularly tubercle bacilli) are made harmless. In some places, "pasteurized butter" is made solely for the latter purpose.

In Denmark, on account of the danger of spreading tuberculosis among animals, it is provided by law that skim milk and buttermilk delivered from creameries to be used as food for animals must have been heated to 85° C. (185° F.). In this connection, however, the law does not mention pasteurization but, in practice, pasteurized separator milk (or buttermilk) is understood to be milk that has been subjected approximately to the above mentioned temperature and that does not react to Storch's or to the guaiac tests.

Since market milk is pasteurized especially in order to render harmless any disease producing germs that may possibly be present, and since the majority of consumers are, doubtless, of the opinion that pasteurized milk may be used with perfect safety without further heating, it should be strictly required that market milk sold as "pasteurized" shall have been subjected to a sufficient degree of heat to kill with certainty all of the pathogenic micro-organisms that are present.

The pathogenic bacteria that are of importance in this connection are the germs of tuberculosis, typhoid fever, diphtheria, cholera and pest and pyogenic cocci and the virus of foot-and-mouth disease. These have been shown by recent investigations to be killed by momentary heating to 70° to 80° C. (158 to 176° F.) and they die at a temperature of 65° C. (150° F.), if this

degree of heat is maintained long enough. This is also true of many bacteria occurring in milk which may be injurious, yet which cause no specific disease. Therefore, milk may be pasteurized either by a brief heating at a higher temperature or a longer heating at a lower temperature. But the spores of bacteria and the thermophilic forms that are specially capable of resisting heat, are not destroyed by these methods, so pasteurization does not have the same effect as sterilization. Milk may be pasteurized in different ways. The following three methods are those most commonly used:

2. The milk is heated during one-quarter to one hour at from 80° to 85° (176° to 185° F.) while it is flowing through an appropriate pasteurizing apparatus; then it is cooled immediately.

2. The milk is heated from one quarter to one hour at about 65° C. (150° F.) in a tank or vat. The milk flows directly from this vessel into the one in which it is to be sold, or it is first passed through a cooler.

3. The milk is poured into well cleansed or sterilized bottles or metal vessels, is then heated for a considerable time at 65° to 80° C. (150° to 176° F.), then the bottles or vessels are sealed and quickly cooled.

For sanitary reasons the last of these methods is unquestionably to be preferred, but it has not been adopted extensively on account of its cost. Heating many small vessels requires a great amount of heat and causes great loss in bottles, if such are used. The initial cost, also, and the amount of labor required are considerable.

If one of the first two methods is employed, the pasteurized milk must be drawn into vessels (bottles or metal cans) which have previously been properly sterilized.

Pasteurizing milk and then placing it in unsterilized

vessels has no effect. Indeed, if bottles are used, this is to be forbidden as injurious to health. Very often the milk is drunk directly from the bottle, which may be infected by this means and, in spite of washing, fresh milk may be infected as it is poured out. In this connection, what is to be understood by sterilization? The aim is, so far as possible, to kill all microbes. The task is not difficult with metal vessels because, after thorough mechanical cleansing, these can be subjected to very hot steam or can be scalded. With glass bottles, the task is more difficult, because strong heat causes much breakage, and if the price of the milk is not such as to cover this loss, another method must be used. Thorough mechanical cleansing, scouring the outside as well as the inside, followed by long soaking, in a strong, warm solution of washing soda at 70° C (158° F.) and rinsing in pure, lukewarm water, is believed to kill with reasonable certainty all pathogenic forms and also the majority of other milk bacteria.

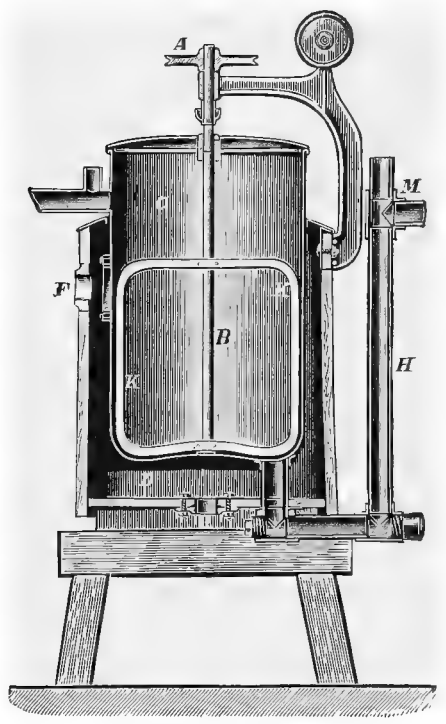
A very large number of machines for the quick pasteurization of milk have been built, chiefly for use in creameries. The principle of these machines is different. One of the first pasteurizers was that made by Fjord; it consists, as the diagrams (Figs. 5 and 6, pp. 132 and 133) show, of a tinned copper tank provided with an insulated steam jacket. The tank contains rotating arms by which the milk is thrown against the heated walls. The milk is admitted at the bottom through pipe *H* and leaves the apparatus at the top.

By regulating the quantity of milk admitted, the rapidity of the revolving arms and the amount of steam, the milk may be heated as desired. Many other pasteurizing machines are built according to the same principle.

In other pasteurizers, the milk is heated while it flows in thin layers over heated metal surfaces, or while

forced between two surfaces lying close to each other, or while it is being passed through a system of heated pipes. In some pasteurizers hot water serves as the source of heat for the metal surfaces or pipes, while steam is used in others.

Fig. 5.



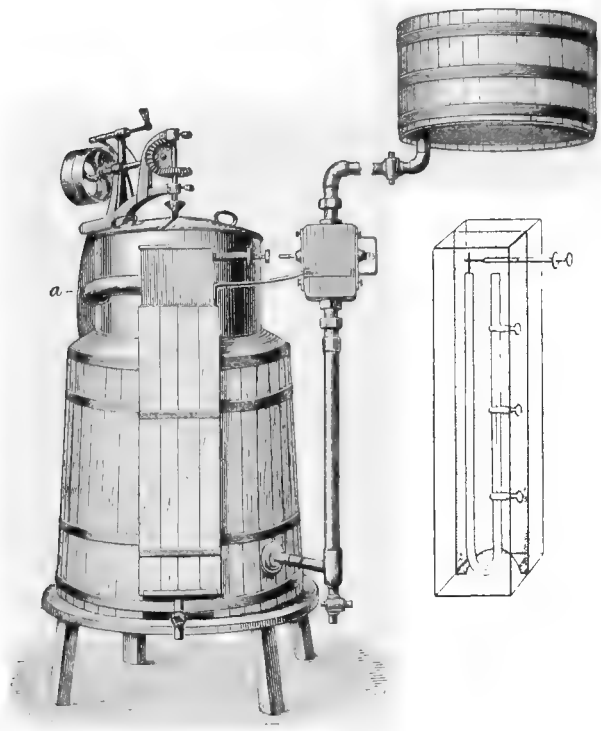
Fjord's pasteurizing apparatus.

Since one can hardly be sure that every particle of the whole volume of milk is heated to a given temperature by this method of pasteurization, it should be required that the temperature of the milk, when it leaves the apparatus, shall be at least 80° C. (176° F.). If this

is not done, it cannot be regarded as certain that the milk has been freed from pathogenic micro-organisms. Moreover, a pasteurizer which is to prepare milk for use as food must fulfil the following requirements:

1. *The entire quantity of milk*, including the froth formed during heating, *must be heated equally* to the desired temperature.

FIG. 6.



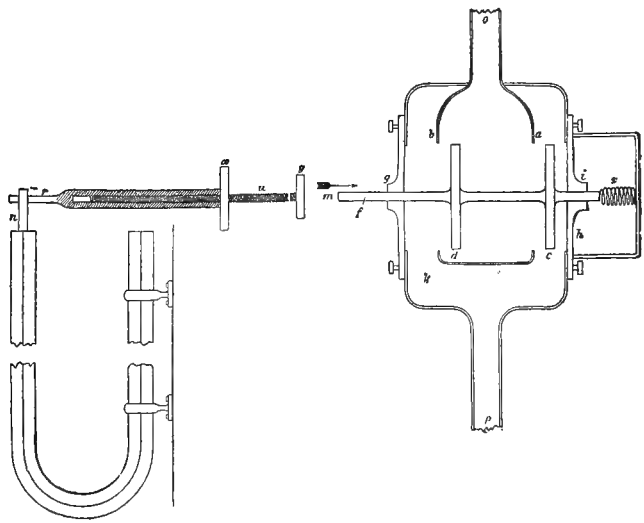
Fjord's pasteurizing apparatus.

2. *The apparatus must work reliably*, in order that there shall be no danger that at times the milk is not sufficiently heated.

3. *The machine must be easy to clean.*

All pasteurizing apparatus must be under the constant inspection of a reliable man, or must be provided with a self regulator. A regulator which shuts off the milk automatically if the temperature of the contents of the machine falls below the given standard, was devised by Henriques and Stribolt. Up to the present time, this principle is not widely applied, but doubtless it deserves to be introduced into the better plants which prepare and sell pasteurized milk. Fig. 6 shows a Fjord pasteurizer with a self regulator; the latter consists of a metal thermometer (see Fig. 7) whose free arm (n) is attached to a horizontal rod ($r\ y$) which may move a valve placed in the entrance pipe to the pasteurizer.

FIG. 7.



Automatic temperature-regulator, as devised by Henriques and Stribolt.

The construction is shown by Fig. 7. As the temperature of the milk in the machine rises, the two arms of the thermometer approach each other and the valve $m\ d\ c$ is thus pressed back by the horizontal rod $r\ u$, which presses against m so that the opening at $b\ k$ is free

and the milk can pass from *o* to *p*. If the temperature falls, the pressure of the horizontal rod is withdrawn from the valve, which is then caused to close the opening by means of a spring, *s*, so that the milk cannot flow to the pasteurizer; thereupon the discharge of milk immediately ceases, and not until the milk has been sufficiently heated will the valve open again, so that fresh milk may enter and expel that already heated from the apparatus.

FIG. 8.

Schmidt's milk-cooler; *a*, entrance for cold water; *b*, exit for cold water.

From the pasteurizer, the milk must be passed over or through a cooler in order to lower the temperature as much as possible, for otherwise it would soon spoil.

From the cooler, the milk should be drawn directly into the container from which it is to be sold. Fig. 8 represents a cooler which consists of a spirally fluted

metal tank, through which cold water or, better, ice water is passed and over the surface of which milk slowly flows.

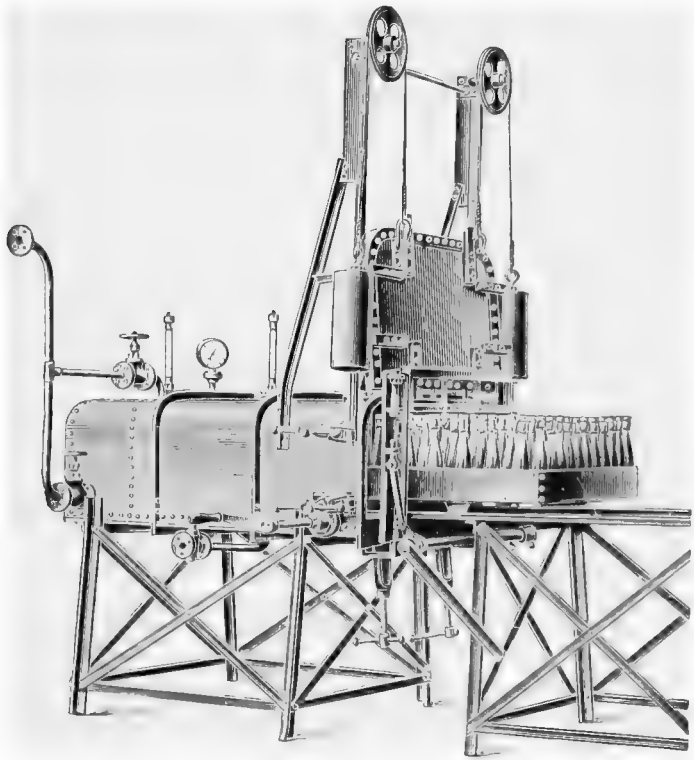
For pasteurizing milk in bottles or in cans an apparatus of different construction is used. Some consist simply of a water bath; a large shallow metal tank is partly filled with water and the bottles are so placed in this that they are submerged as close as possible to the neck, then the tank is closed by a cover and the water is heated with steam.

Other pasteurizers are built according to the following principle: there is a perforated drawer in a large metal tank upon which the filled bottles are placed close together (Fig. 9); after the tank has been tightly closed by means of a cover or door, steam is admitted until the desired temperature is reached. Of course these machines are also adapted to sterilizing at a higher temperature (100° to 110° C., 212° to 230° F.). After from one-half to one hour's heating, the bottles are allowed to cool a little before the tank is opened, then they are immediately sealed. In some machines, all of the bottles are sealed before the tank is opened, by means of a specially arranged mechanism. The further cooling of the bottles is attended with certain difficulties, as they crack easily. This may be accomplished by passing the bottles through several tanks of water of progressively lower temperature, or by slowly lowering the temperature of the water surrounding them.

While the fact of the previous heating of milk to not less than 80° C. (176° F.) may be established with certainty by the Storch or guaiac tests, it is not possible to determine whether or not the milk has been subjected to a less degree of heat; moreover, since a brief heating at 80° C. (176° F.) is cheaper and far more convenient than a longer heating at, for instance, 65° C. (150° F.), there

is much to be said in favor of the establishment of a fixed rule that all milk designated as pasteurized shall be heated to at least 80° C. (176° F.), that is, a temperature that can be determined by the Storch or guaiac test. But there is another side to the question. In the medical

FIG. 9.



Flaack's apparatus for sterilizing bottled milk.

world the sentiment against pasteurizing at high temperatures has been growing during recent years, for it has been claimed that this causes a change in the proteids which makes them less digestible. In many places, therefore, the longer heating at a lower temperature, has

been adopted. All milk from Bolles' great establishment in Berlin, is handled in this way.

Under these conditions, such a requirement as that mentioned above could scarcely be maintained but, without doubt, regulations with regard to the sale of pasteurized milk should be laid down, and the following appear to be appropriate:

1. *Milk sold as "pasteurized" without a more explicit statement must have been heated to at least 80° C. (176° F.).*

2. *Milk that has been pasteurized by heating at a lower temperature, shall be sold as "pasteurized" only if it is marked with a label giving the degree of heat applied, and not until after the health authorities are convinced that the establishment in question is prepared to pasteurize in an approved and effective way.*

The advantages derived from pasteurizing market milk, from a hygienic standpoint, are as follows:

1. The specific pathogenic bacteria are destroyed.

2. Most of the other bacteria are likewise killed and, therefore, the milk keeps better.

3. Pasteurization necessitates a better method of delivering milk than that commonly employed in many places.

By means of pasteurization, as has been said, the pathogenic bacteria and the larger part of the other bacteria are killed. Since the bacterial content of ordinary milk is most variable, and since the forms are by no means always alike, the number of bacteria that live through pasteurization—even after heating to the same temperature—is not even approximately the same. In other words, the average bacterial content of milk that has been pasteurized a short time cannot be stated. There are usually only very few bacteria per c.c. in pasteurized milk that was freshly drawn and handled in a

cleanly way; while under other conditions hundreds, even thousands of bacteria are to be found in every c.c. of pasteurized milk. Lactic acid forming bacteria in milk are killed by pasteurizing, while certain harmless bacteria, many bacteria of putrefaction and spore forming bacilli survive; for this reason *pasteurized milk seldom sours but gradually putrefies.*

No absolute conclusions can be drawn concerning the effectiveness of pasteurization from the bacterial content of pasteurized milk sold in the retail market, for one does not know the nature of the milk before pasteurization, the length of time the milk has been kept since pasteurization or the temperature at which it has been kept, and these factors are largely responsible for an abundance of bacteria.

The objections to pasteurization are:

1. Even by the use of a self-regulating pasteurizer, it is difficult to provide absolute guarantee that *all milk* has been heated to the required temperature.

2. Pasteurization incurs expense, therefore the milk costs more.

3. To a certain degree, pasteurization may conceal a tainted condition which exists before heating. Quite an abundance of bacteria of putrefaction and other bacteria may be present, or the lactic acid fermentation may have begun to take place; these bacteria are killed by pasteurization, consequently the fermentations and changes that were under way are interrupted. Under such circumstances, one cannot tell by the appearance or taste of milk that it is damaged and that it contains the products of decomposition of the albumen, or, possibly, even toxic substances. On the whole, there is no way, at the present time, of determining whether or not pasteurized milk was damaged before it was heated, while, with respect to raw milk, the keeping quality and bac-

terial content furnish sufficient evidence regarding its true condition.

4. The bacteria surviving pasteurization are, for the most part, the quick growing bacteria of putrefaction which are inhibited in raw milk by the lactic acid bacteria, but in pasteurized milk they multiply very fast and undoubtedly they are capable of generating poisonous substances. It has been suggested, therefore, that a pure culture of lactic acid bacteria be added to milk after pasteurization in order to check the bacteria of putrefaction.

5. In purchasing pasteurized milk, one cannot tell if

Number of Bacteria in 1 c.c.	Number of Samples	
	Ordinary whole milk	Pasteuriz'd whole milk
0–10		2
10–50		–
100–500	–	2
500–1,000	–	4
1,000–5,000	–	1
5,000–10,000	–	10
10,000–20,000	–	6
20,000–50,000		12
50,000–100,000	–	7
100,000–1,000,000	7	66
1,000,000–5,000,000	1	20
5,000,000–10,000,000	–	9
Above 10,000,000	1	3
Total number of samples...	9	142

it be fresh or old and cannot determine, from its appearance, if putrefaction has begun or if only a few bacteria are present. That this objection to the sale of pasteurized milk is valid, is shown by the Copenhagen health

Commission, in its report, especially that for 1899, on the number of bacteria in pasteurized milk, as compared with the number in unpasteurized milk.

It is evident that these figures do not seem to favor pasteurized milk, and the situation is still less favorable if one considers that the bacteria in raw whole milk are chiefly lactic acid bacteria, while in pasteurized milk the greater part consist of bacteria of putrefaction. The figures above cited for the year 1899 are especially high, but the summary given below is made from examinations of pasteurized milk extending through a period of several years:[37]

Number of Colonies in 1 c.c.	1896	1897	1898	1899	1900
Below 100,000	22	26	12	44	40
100,000-1,000,000	1	5	19	66	39
Above 1,000,000		1	17	32	26
Total number of samples	23	32	48	142	105

This increase in the number of strongly infected samples occurs coincidently with the equipment of many milk establishments for the production of "pasteurized" milk and apparently without such careful direction as to make it certain that the whole quantity of milk was really heated to the required temperature; that this was the case is indicated by the result of investigations of the health commission in the year 1899, which show that of 36 samples of pasteurized cream 2, and of 389 samples of pasteurized milk 23 could not stand the

[37] Stadslaegens Aarsberetninger (Annual Report of the City Physician). Copenhagen.

Storch test, which showed that they had not been heated to 80° C. (176° F.).

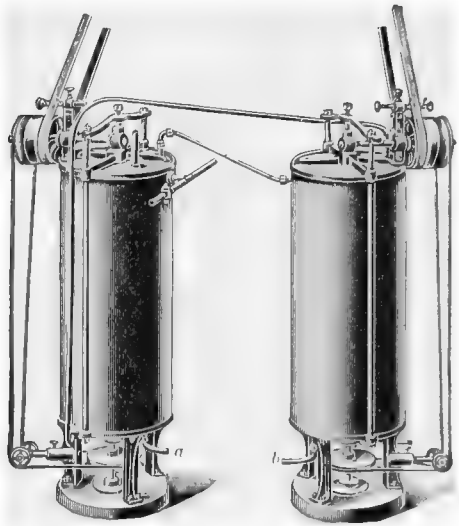
When we compare the advantages and disadvantages it will be found that *there is serious doubt as to whether it is advisable to endeavor to obtain general pasteurization of market milk,* as has been suggested by many. A well organized and well conducted large milk business may be in position to carry out pasteurization with safety and to obtain all the various advantages that result from this process but, undoubtedly, it would be necessary for the great majority of establishments to be kept under comprehensive, strict and expensive control by the health authorities which, even then, could scarcely be effective.

II. STERILIZATION

By sterilization of milk is understood a long continued boiling, or heating to a temperature above the boiling point as 105° to 110° C. (220° to 230° F.). The superiority that is claimed for sterilization over pasteurization is that all of the bacteria are killed and the milk, consequently, will keep for an unlimited time. But nearly all the examinations of "sterilized milk" bought in the market, that have been made, up to the present time, have shown that the milk is not sterile but contains the spores of bacteria. On the whole, sterilization offers no special advantage over pasteurization, on account of the unpleasant taste of sterilized milk, due to changes in the albumen and lactose, and on account of the greater expense connected with it. Sterilization has the advantage only when it is a question of keeping the milk a long time or transporting it a long distance, and in this case the principle followed is essentially the same as that followed in the preparation of preserves in

hermetically sealed cans. Considerable advance has been made in recent years in regard to the preparation of such preserved, canned, milk, in that the boiled and

FIG. 10.



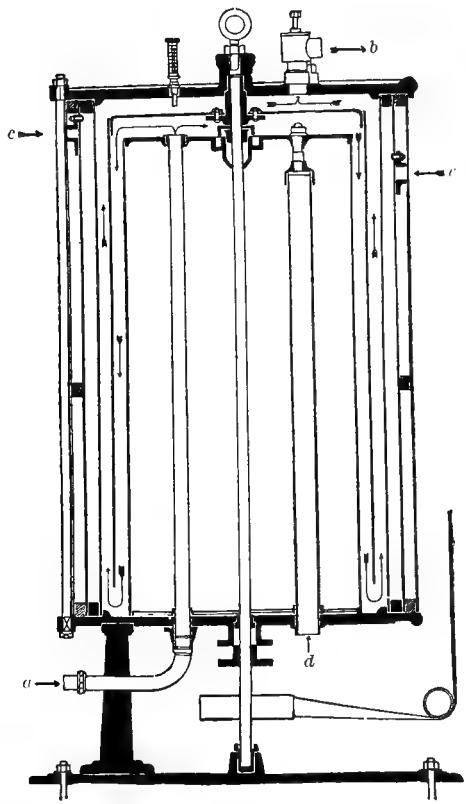
Kleemann's high-pressure pasteurizer and regenerative heater. *a*, water of condensation *b*, to the cooler.

burnt taste has been prevented by pumping the air out of the milk before heating it and by the exclusion of oxygen during heating, so that a high temperature is possible and a safer sterilization is accomplished without seriously affecting the taste. Another difficulty which it has been necessary to contend with, the separation of cream, and of butter formation during storage, seems by degrees to have been overcome.

For the purpose of sterlizing milk, instead of the usual apparatus built according to the Fjord system, tightly closed machines are used, so that the temperature of the milk can be raised above the boiling point, and through these the milk is forced by means of a small

pump. There is a large number of such machines. In Germany they are commonly used for simple pasteurization. Of the machines most used in recent years, the

FIG. 11.

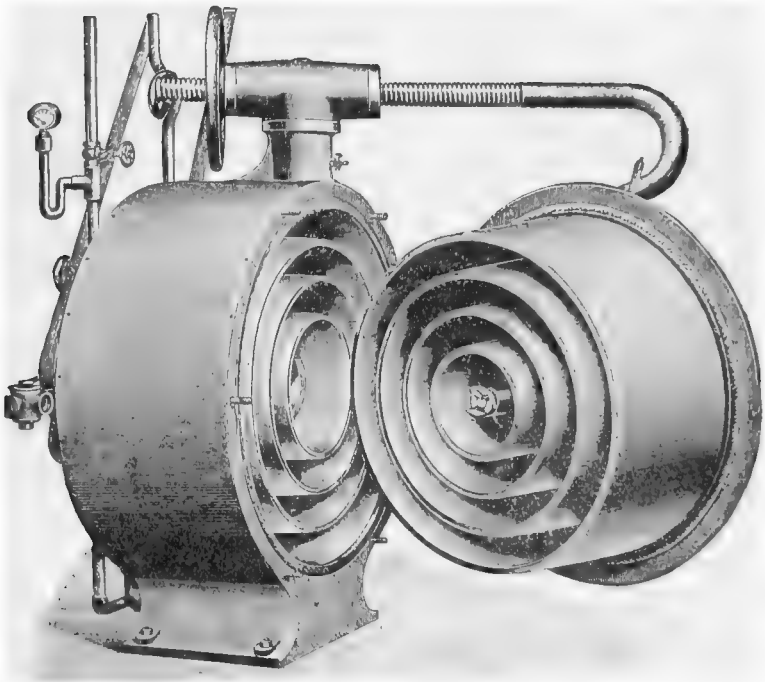


Section, to show construction of apparatus shown in Fig. 10. *a*, entrance for milk; *b*, exit for milk; *c*, steam-chamber; *d*, steam-opening; *e*, safety-valve.

so-called "regenerative heater" is to be commended because it saves much steam. It is built according to the principle that the hot milk flows past the entering cold

milk (only a thin metal plate separating them) so that both streams of milk have opposite directions; by this means, there is the advantage that the hot milk, even before it leaves the sterilizer, is somewhat cooled without expense, while the cold milk gains quite a little heat before it is heated by the action of the steam. In this way,

FIG. 12.



Mor's regenerative milk-heater.

steam, as well as ice, is saved. Machines built in accordance with this principle differ much in appearance. Some, for example the apparatus shown in Fig. 10, which is one of the newest, consists really of two parts, the sterilizer proper (the "high pressure pasteurizer") and an apparatus quite similar ("the regenerative heater")

in which the stream of warm milk works upon the incoming cold milk. Both parts have the same construction, which is easily seen from Figs. 10 and 11. Other machines of this kind (for example, Mor's regenerative milk heater, Fig. 12), are simpler in that both processes take place in the same machine. For sterilizing milk measured into bottles, machines which are described and figured on pages 136 and 137 (Fig. 9) are used.

PART V.

THE USE OF MILK FOR INFANTS

The advantages of milk as a general food for man are so well known that no further discussion is necessary; but the special use of milk for infants, as a substitute for mother's milk, offers certain points of interest which merit further consideration. It is logical first to review the behavior of milk and the changes that occur in it during digestion.

Under the influence of the gastric juice, the proteids undergo a process of splitting up in the stomach. The albumin and globulin are first changed into syntonin and then separated into albumoses and, probably, peptone. Casein behaves somewhat differently. It is transformed by the hydrochloric acid of the gastric juice into an acid calcium salt and then, under the influence of *rennin*, it undergoes a change, during which whey albumin is formed, into calcic paracasein, which separates as a curd. The calcic paracasein is then split by pepsin into albumin and paranuclein (pseudonuclein) which is precipitated but which is afterwards dissolved by the prolonged action of the gastric juice, being broken up into an albumin-like material and phosphoric acid. The albumins that are formed by splitting of the casein are later changed into albumoses (caseoses) and peptone. According to recent investigations it appears that these substances may undergo still other changes before they are absorbed. Through the action of rennin, an albumin-like substance (plastein) is formed and through the

action of an intestinal ferment (erepsin) the splitting of peptone is continued into di- and mon-amido acids. Little is known as to the resorption and use of these substances.

There is a difference of opinion regarding the fate of the milk sugar; some think it is absorbed from the intestines unchanged, but others are convinced that it is first inverted into dextrose and galactose. The absorption takes place more slowly than is the case with glucose, maltose and cane sugar.

The absorption of milk-fat takes place as that of other fats, with a preceding saponification.

It is well known that cow's milk is being used more and more as food for infants and for small children. As a substitute for mother's milk, there are some objections to it, however, and if used for nursing babes, it must receive especial treatment. This is on account of the fact that it differs materially in chemical composition from human milk and that it constantly contains micro-organisms, and, sometimes, even pathogenic forms.

The differences in composition of human milk and cow's milk are shown by the averages given below:

	Water.	Casein.	Albumin.	Fats.	Lactose.	Salts.
Woman's milk...	87.92	0.58	0.52	3.43	7.12	0.2
Cow's milk.....	87.75	3.00	0.50	3.40	4.60	.5075

[Human milk appears to vary more in composition than cow's milk. This may be due in part to the greater difficulty in obtaining a fair sample than is the case with cow's milk. It is known, for example, that the composition of the fore milk and the strippings differ considerably, and if small samples of milk are drawn from a cow's udder at irregular times during the day, before and after regular milkings, the samples will be of very different composition. Besides this, the less regular life

of the woman and the nervous influences to which she is subject may tend to make her milk more variable than that of the even-going cow.

The figures, however, that are given in the above table show less proteids than were found by most of the leading authorities. The average composition of woman's milk, as determined by a large number of analyses, is given by Richmond as follows:

	Water.	Proteids.	Fat.	Lactose.	Ash.
Woman's milk	88.2	1.5	3.3	8.8	02.

Johanssen, however, found but 1.1 per cent. of proteids, as an average for 25 samples, thus agreeing, in this respect, with the figures given on page 148 which are from Gottlieb. L. P.]

The first thing to be considered is that the quantity of total proteids in cow's milk is more than three times [or more than twice] the quantity in human milk, so that a child nourished with cow's milk has apparently a considerably greater nitrogen assimilation than a child nourished in the natural way. It is not known with certainty what significance this has for the health of the child, but it is not safe, off hand, to conclude that the highly nitrogenous diet is advantageous. Moreover, the chief part of the protein of cow's milk consists of a casein, which, in contrast with the casein of human milk (the proteids of human milk do not give a curd with rennet), is precipitated in the stomach as large curds and in a form that apparently makes it less digestible.

Great importance has been attributed by some to the fact that human milk often contains more fat than cow's milk and, it is affirmed, on this account the nutritive value of human milk is greater than cow's milk. But since we know that the fat content of human milk is subject to great variation (for individual peculiarities see page 24) no particular importance can be attributed, in

general, to this difference. On the other hand, the fact must be considered that the fats in the two kinds of milk differ somewhat chemically, and that cow's milk contains much more volatile fat (butyric acid) than human milk. These other important conditions should be mentioned: the decided different proportions of lactose which, doubtless, is of value in the nourishment of the child, and the small quantity of lecithin in cow's milk, to which great importance is now ascribed in metabolism. It is doubtful if the greater quantity of citric acid and of inorganic salts in cow's milk has an unfavorable influence on the nourishment of the child.

Many attempts have been made to correct the defects of cow's milk and to make it a more appropriate food for infants.

By diluting cow's milk with water, the percentage of salt is proportionately decreased so that the casein coagulates in the stomach in flakes, just as the casein of human milk, and at the same time there is a proportionate diminution in the percentage of the total proteids. But there is also a decrease in the quantity of albumin as well as of the other ingredients of great nutritive importance—lecithin, lactose and fat—which is decidedly disadvantageous. In order to remedy this, the milk is often diluted with barley- or oat-water or the proper quantity of milk- or grape-sugar is added. Others have used cream diluted with water; by this means an appropriate quantity of protein and fat can be had, and since fat may be substituted for lactose, the deficiency of the latter makes little difference.

To make cow's milk approach human milk more closely, and to make it more easy of digestion many methods of preparation, some of them rather complex, have been proposed, and some have been used commercially. The following are examples of such preparations:

"*Gärtner's fat milk*" is prepared in the following way: cow's milk is diluted with water to such an extent that the casein content corresponds to human milk, then it is so centrifuged that the milk flowing from the cream tube has a fat content which agrees with that of human milk. The milk is put into bottles and sterilized. The composition of the "fat milk" may, of course, be changed at will; the average composition of such a preparation made in Germany is: fat, 3.7 per cent.; proteids, 1.5 per cent.; lactose, 2.2 per cent.

"*Voltmer's mother's milk*" is the name given to a milk preparation that is sometimes marketed in the form of "milk," and sometimes is condensed and sold in cans. The preparation is somewhat complicated; fresh centrifuged cow's milk is heated to 100° C. (212° F.) and distilled water, cream and sugar are added to it in such quantity that the content of proteids, fat and sugar correspond to human milk; the mixture is now exposed to the action of pancreas ferment which process changes the casein into albumoses. The preparation is sterilized at 102° to 105° C. (215.6° to 221° F.) or evaporated and poured into cans which are sterilized after soldering. According to several analyses, the composition of the commercial product is, approximately: fat, 2.3 per cent.; proteids, 1.8 per cent. (about three-fourths of this is albumose); sugar, 6.2 per cent.; and salt, 0.4 per cent.

"*Backhaus's infants' milk*" is similarly prepared. The cream is separated by the centrifuge; the skimmed milk is heated to 40° C. (104° F.) and rennet and trypsin are added. In the course of half an hour the precipitated cheesy mass is filtered out; by this means a part of the casein can be taken out, while the rest is transformed into easily digestible albumoses. The action of the ferments is stopped by heating, and cream and sugar

of milk are now added. The preparation, which is marketed in a sterilized condition, has been widely recognized. Its composition may easily be varied. For small children a preparation of about the following composition is made: fat, 3.1 per cent.; casein, 0.6 per cent.; albumin, 1.0 per cent.; lactose, 6 per cent.; ash, 0.4 per cent.

Gottlieb has proposed that sweet whey, cream, sugar of milk and lime water may be mixed together in such proportions that the composition of the mixture will closely resemble human milk.

[*"Modified milk"* as developed and prepared by the Walker-Gordon Laboratory Company, with the scientific aid of Dr. T. M. Roach, has been in use in the larger cities of America and in London for a number of years; it was first prepared and sold in Boston in 1891. Such milk is dispensed upon physicians' prescriptions, and is prepared by mixing whole milk, cream, whey, skim milk, lactose and water or other substances, if ordered, as lime water, starch, barley-water. etc., in the proportions required to give accurately the desired percentages of protein, fat, sugar, etc. It is dispensed in round bottles ("tubes") each of which contains sufficient milk for a single feeding. The bottles are plugged with cotton-wool. The milk is produced on farms belonging to or under the control of the company and most exacting precautions are taken to protect it from contamination.

The milk is served raw, pasteurized or sterilized, as ordered. Usually it is pasteurized and if the proteids consist chiefly of those present in whey, the temperature reached during pasteurization is not permitted to exceed 155° F. By means of modified milk the nutritive requirements of the individual child can be supplied. L. P.]

Many special preparations similar to the above have been used abroad and have received the approval of pediatrists. In Denmark, however, they are used but little and they will never have a very broad field on account of their high price.

In France, asses' milk is quite commonly used as a substitute for human milk and in Dresden an establishment has been started for the production of asses' milk, which is desired partly because of its great similarity to human milk and partly because of its favorable effect in indigestion of children. On account of the small milk yield of the donkey, this milk is much too expensive to be used generally. For the same reason, mare's milk has been used in some places, but only to a limited extent.

Goat's milk has been suggested as food for infants, and large herds of goats have been maintained in some places for this purpose—principally on account of fear of tuberculous infection from cow's milk. The prevalent opinion of the infrequency of tuberculosis in goats is untenable, since they are very easily infected and may suffer, just as cows do, with udder tuberculosis. Therefore, there is no reason to prefer goat's milk to cow's milk.

In by far the majority of cases in which the mother has not enough milk, or her child will not nurse, cow's milk is used as a substitute. The question has often been discussed as to whether and, if so, what special requirements should be made for milk intended for infants, and different answers are given. It was formerly thought that the composition of the cow's food had a marked influence on the chemical composition of her milk, and upon its character, and on account of this opinion it was formerly required in Germany that cows kept for this purpose must be fed nothing but dry food the entire year. The price of such milk has been considerably in-

creased on this account. In Denmark also, similar, though less strict, requirements were made for the production of milk for infants. During recent years, however, views concerning the effect of the forage on the quality of the milk have changed materially, and it has been observed by many that babies have been fed without discoverable detriment on milk from cows fed with green fodder, turnips, oil cakes, etc., and, indeed, in some instances, with brewery grains. There does not appear to be adequate ground for the requirement that cows kept to produce nursery milk should be restricted to this one sided diet. On the other hand, there is need for an active control of the sanitary conditions of the producing herd, for the public must be assured that milk sold at a high price especially for the use of infants may be fed to them without danger of a grave infection of some kind. The nature of the requirements which, in our judgment, should be made concerning the production, handling and sale of " nursery milk " are considered later.

The mortality among children during the first year of life is very significant. In Norway and Sweden, from 1891 to 1895, on the average, 10 per cent. died each year; in Denmark, 14 per cent.; in Finland and Switzerland, 15 per cent.; in Prussia, 20.5 per cent.; in Baden, 22 per cent.; in Würtemberg, 25 per cent.; in Bavaria, 27 per cent.; and in Saxony, 28 per cent., while the mortality in Austria and Hungary is 25 to 28 per cent. The mortality is greatest in large cites, somewhat less in small cities and least in the country.

Different cities show different death rates; for example, from 1886 to 1895, on an average, each year 13 per cent. of the children less than one year old died in Lyons, 15 per cent. in Christiania, 16 per cent. in Paris and London, and the death rate in Berlin reached 25.3

per cent., in Budapest 28 per cent., in Munich 31.4 per cent. and in Ingolstadt even 40.9 per cent.[38]

In Copenhagen, the mortality, during the first year of life, has decreased significantly; 1877 to 1886, 20.83 per cent. died each year; in the next decade 19.04 per cent., during 1897 to 1899, 17.87 per cent., while only 15.55 per cent. died in 1900. Infant mortality is also on the decrease in the provincial cities, and this is certainly true of many large cities abroad.

A comparison of normally fed children with children fed on raw or prepared cow's milk, shows a far greater death rate among the latter. If the cases of diseases and death are arranged according to the separate months, it is noticed that in most cities there is a marked increase of deaths in July and August and a proportionate decrease in September, and this increased mortality pertains almost exclusively to children fed artificially.

By far the greater part of the fatal diseases are affections of the stomach and the intestines as catarrh, colics and cholera infantum. Although the causal conditions are not fully explained, it may be stated that cow's milk appears to induce a predisposition to intestinal infections, on account of its varying and heterogeneous composition. The diseases are to be attributed to the action of microbes; possibly in some cases to bacteria that have formed toxic substances during their development in the milk, but in the greater number of cases it is, doubtless, a question of the presence of pathogenic microbes in milk (streptococci, proteus- and colon forms). Therefore, milk intended for infants should be sterilized. Opinions differ as to whether heating with steam for an hour (Soxhlet's method) is to be preferred

[38] These figures are taken from Ohlens' Die Milch und ihre Bedeutung, 1903.

to brief boiling or to pasteurization, since it is thought that long cooking affects the digestibility of the casein.

Through the zealous efforts of physicians, it has been possible, during recent years, to cause the general acceptance of the practice of sterilizing milk for infants and the reports show that this has had a favorable influence in preventing disease and death.

There are, however, *some children with whom cooked cow's milk does not agree,* as it causes continual indigestion and loss of weight so that, indeed, when six months old they may weigh less than at birth (infantile atrophy). This condition is often improved at once if a wet nurse is procured for the child or if asses' milk is used; or a change to raw cow's milk may lead to quick recovery. An explanation of these different effects of cooked or raw cow's milk cannot be given here, since there is no convincing reason for the opinion that cooked milk is harder to digest than raw. Possibly the favorable effect of raw milk can be attributed to the presence of substances antitoxic to some of the poisons absorbed from the intestinal canal, which antitoxins are destroyed by heating the milk. [In America, the balance of opinion among pediatrists appears to be in favor of clean, raw milk, specially produced, of low bacterial content and from a reliable source (" certified milk ") ; or milk that has been pasteurized at a moderate temperature (155° to 185° F.) and that has not been boiled. L. P.]

PART VI.

PUBLIC CONTROL OF THE PRODUCTION AND HANDLING OF MILK

Naturally there are great differences in different countries in the way cities are supplied with milk and in the manner in which it is handled after it reaches the cities. In general, it may be said that there is no difficulty in supplying small towns, as herds are sometimes to be found within their limits and usually enough milk is brought in from the immediately outlying districts. It is different with the larger cities and, with respect to them, the milk business has been greatly changed during the last 20 to 30 years. The conditions in Copenhagen may serve as an example, as they do not differ materially from those found in other large European cities. Copenhagen was once supplied with milk chiefly from the brewery herds and other herds within the city, and by farmers from the adjoining country, who delivered milk to their own regular customers in the city; now the conditions are wholly changed.

The continual growth of the city and the constantly increasing hygienic demands have caused the almost complete discontinuance of cattle keeping within the city, and proximity to the large city has greatly affected the character of the farming nearby, so that the breeding of cattle and dairying have fallen off. On the other hand, on account of easy transportation by railroad, farmers living at quite a distance can deliver their milk to advantage in Copenhagen, and at this time the city is

supplied with milk not only from the island upon which it is situated but also from the surrounding islands. This facility of transportation by railroad and boat has led to the establishment of milk depots that receive the milk from the farms, handle it appropriately and deliver it to their customers, selling it either from established sales places, or from wagons.

This evolution in the handling of milk, which has occurred in most of the large cities of other countries as well, marks an important advance in hygienic methods. The milch herds in the cities and the retail shops connected with them were very often the source of grave epidemics; the uncontrolled sale of milk by small farmers has had the same unfortunate result, and there is danger, too, in the small shops, as the limited space makes it difficult to prevent the various members of the family from coming into too close contact with the milk containers and with the milk itself.

Large companies are better able to bear the expense resulting from the observance of hygienic requirements, and the sanitary control of these may be much more easily effected than in the case of numerous small concerns. It is to be observed also that many of the large milk establishments have voluntarily adopted standards for the production and handling of milk that are in advance of requirements of the health authorities. There are no proven cases of milk epidemics traced to infection through milk from *well conducted* large concerns; no doubt the mixing of a large quantity of milk lessens the danger of infection, since usually a certain amount of infectious material is necessary to produce infection. On the other hand, however, the mixing together of a great quantity of milk, *under unfavorable conditions,* may be particularly dangerous because if a milk epidemic were caused it would be very widely spread.

A strictly enforced control is, therefore, no less necessary for large establishments than for small.

The first large milk company established in Copenhagen was the Copenhagen Milk Supply Company which, more than 25 years ago, at a time when milk hygiene was still on a low plane in Denmark, as it was abroad, established, voluntarily, a comprehensive standard covering the condition of health, the cleanliness and the feeding of the herd, the health of the milkers and other employees and the proper handling of the milk. This company rapidly developed a very important business and has been imitated in Denmark and in other countries. Several new companies have made even greater advances in the adoption and enforcement of hygienic requirements. Moreover, the large, well organized milk companies have had a very great influence in forcing the small concerns to handle their milk with much greater cleanliness and care.

The most familiar ways of retailing milk in cities, are: the milk is drawn and sold in established shops or it is drawn or dipped from tanks carried on wagons, or, thirdly, the milk is first bottled, or is placed in cans that are closed and sealed. The last method is decidedly the best and it is now rapidly displacing the other methods. When milk is measured out on the street, it may easily be contaminated by dust and dirt blown about by the wind, and as the delivery buckets are carried from one kitchen to another, there is a possibility that they may carry contagion. This method of delivery is also attended by the possibility of defective measuring, etc., by the deliveryman.

The hygienic requirements that should be established with relation to the milk supplies of cities, will doubtless lead to a further change in the milk business as this is apparently going more and more into the hands of a

few large companies while the number of small concerns is steadily decreasing.

[In America this tendency toward centralization of the business is very marked in most large cities, and especially in New York and Boston. The reason, however, is economic and is similar to the causes for consolidation in other lines of trade. L. P.]

Since milk, as has been said, can acquire harmful properties in different ways, since its composition may vary considerably, and since it may be adulterated in many ways, the milk business must be supervised by public authority, under appropriate laws or ordinances. Formerly, in most large cities, the occasional examinations had reference only to the fat content of the milk (transparency test, determination of the specific gravity, etc.), and in many places, even at the present time, no further progress has been made. But our present knowledge makes it obvious that such an examination, in comparison with the standard that should be established to guard against dangerous milk, has relatively little importance. The public control, therefore, is not to be limited to an examination for adulteration and souring or " spoiling " of milk on the market, but must extend to the production and the care and treatment of the milk (including the condition of health of those persons who come into direct or indirect contact with it). The enforcement of complete regulations for this purpose, of course, is accompanied with great difficulties, and there is no city in the world whose measures in this respect can be said to be ideal. A point to be avoided in such a control is a great increase in expense which would raise the price of milk. This would be a hardship for the public, the importance of which from the economic and hygienic view points, must not be underrated. In the inauguration of a thorough-going supervision it may

be necessary to interfere considerably with the methods of producing and handling milk as these have gradually developed. Local conditions will have an important influence on the establishment of a system of control and will determine the rapidity with which the various requirements can be fulfilled.

General laws governing the production and handling of milk, are lacking in most countries. Only a few countries (*i.e.*, Portugal in 1900) have enacted such laws and there is not much evidence as to the practical success of these requirements for a whole country. In a large number of the cities of Europe somewhat detailed regulations have been adopted in regard to the milk trade; but these regulations, even in the same country, differ very much. Dresden may be mentioned as an example of a large city with excellent modern regulations for the handling of milk. (Published July 31st, 1900, with amendments of February 26th, 1901.) In order to establish a uniform system in Prussia, the Prussian government in 1899 published a circular of information to municipalities with detailed instructions for a judicious regulation and supervision of the milk trade. In many of the small cities there is either no control at all or a very defective one.

[The following table from a report by H. E. Alvord and R. A. Pearson on the milk supply of 200 cities and towns in the United States shows the subjects of most frequent legislation in connection with market milk in 126 cities, the milk ordinances and regulations of which were examined with especial care. The most popular subjects for legislation are readily seen.

Subjects.	Number of cities	Subjects	Number of cities
Dairies:		**Care of milk:**	
License or permit required	12	Milk vessels to be nonabsorbent	55
Special authority for inspections	58	Milk vessels to be thoroughly cleaned	32
Pure water supply	8	Milk to be promptly removed from the stable	11
Drainage of barnyards	12	Straining	9
Stables:		Cooling and aërating	15
Proximity to other buildings	6	Conditions of storage	23
Light	15	**Sale of milk:**	
Ventilation	32	Licenses, or permits	92
Floor space	15	Licenses to be publicly displayed	24
Air space	10	Source of supply to be posted	14
Cleanliness	47	General inspection in cities	75
Removal of manure	25	Signs on wagons	79
Drainage	17	Unsanitary milk prohibited	109
Other than dairy animals to be excluded	4	Confiscation of impure milk	30
Sanitary milk room	14	Definite standard for composition	67
Employees:		Skimmed milk prohibited	12
Personal cleanliness	20	Skimmed milk permitted conditionally	61
Contagious disease (to be reported)	15	Bottling at farm	8
If exposed to contagious disease	25	Storage of milk for sale	23
Cows:		Milk tickets to be used but once	16
Provisions for examination	58	Milk wagons to be covered	12
Diseased cows	24	Milk wagons not to carry garbage	5
Unwholesome food forbidden	77	Sellers to register customers	7
Pure water supply	40		
Cleaning cows	27		
Milk rejected at calving time	33		

L. P.]

While the establishment of milk control on the part of the public leaves much to be desired, private initiative, as mentioned before, has led to significant sanitary improvement, in that large stock companies have been formed in many cities to provide sanitary milk and have voluntarily subjected themselves to extra expense for guaranteeing and controlling it. In some respects, this voluntary control far surpasses what the public could impose at this time. Appendix I gives the requirements of the youngest company in Copenhagen ("Trifolium"), which shows how far a private company may carry this sanitary control, and these regulations may well serve as a model for other places.

While the companies referred to established their own requirements and determined the extent of the control to which they submitted, another very successful plan has been inaugurated in Stockholm, which consisted in the establishment, in 1885, by private initiative, of a milk commission of 9 members, including 4 physicians, 1 veterinarian and 1 chemist. The members of this commission are chosen in part by the Board of Health and in part by the Medical Society. This commission has outlined a comprehensive control, which includes all who desire it and who are ready to bear the expense connected with it. The business advantages of this control are such that a higher price than usual is obtained for the milk produced under it.

Since the legal requirements in the different cities vary and are adapted to the local conditions, it is not possible to give a concise, epitomized view of existing regulations;[39] the following, however, is an

[39] For a review of the local milk inspection laws of the United States and recommendations, see "The Milk Supply of Two Hundred Cities and Towns," by H. E. Alvord and R. A. Pearson. U. S. Dept. of Agr., B. A. I. Bulletin No. 46, Washington, 1903.

attempt to define the requirements which, from a sanitary standpoint, are to be considered necessary or desirable.

In order to be effective, the legal or police requirements covering the milk trade, must contain detailed regulations concerning:

The production of milk.

The care and handling of milk.

The prevention of adulteration.

The prevention of the sale of tainted or damaged milk.

In respect to the enforcement of these regulations in cities, the supervision will rest—at least in Denmark—with the local health authorities, and preferably with a veterinarian appointed by this authority, who will conduct the inspection of the milk establishments with the coöperation of the police, and take the necessary samples for further examination. In small cities, the inspection of the production of the milk may also be undertaken by the same veterinarian; but in the larger cities, as a rule, this is left to the local veterinarians in the country, and the various dealers or herd owners are required to furnish certificates, that should be drawn up on a prepared blank and be submitted to the health office concerned.

I. REGULATIONS REGARDING THE PRODUCTION OF MILK

Public supervision of the production of milk presents great difficulties and has been carried out in but a few places. In the ordinances of most cities, there are certain requirements pertaining to the production of milk, but their enforcement is not always provided for. In several cities every owner of cattle who delivers milk in the city, either directly or indirectly, is obliged to appear before a public authority and pledge himself to observe

the existing legal requirements or those that may be made later, and especially to report every change in the make up of his herd. This is a good arrangement. The actual observance of these requirements should be controlled by frequent visits of a veterinarian appointed by a central authority or by occasional visits of the local veterinarian, but the latter plan is not so satisfactory.

Such a regulation would, of course, be particularly difficult in large cities as, for example, Copenhagen, which receives milk not only from a very large number of large and small herds, the cows in which are often changed, but is supplied with milk from a large part of the country. On the other hand, the regulations mentioned can be adopted without great difficulty in small cities, although they might cause dissatisfaction at first among the dairy farmers. In most of the larger cities, up to the present time, little has been done except to publish notices in regard to the regulations respecting the production of milk, but no reports have been demanded of producers and no special control has been provided to enforce these regulations. The local boards of health have the right to investigate cases which are reported and if necessary to forbid the sale of milk from the premises involved.

[In the United States, there is a certain amount of dairy farm inspection under the authority of the states. In Massachusetts, herds are inspected by the Cattle Bureau of the Board of Agriculture, in Pennsylvania by the State Livestock Sanitary Board, on request from local boards of health that their milk supplies be examined into; in several states, herds and premises are inspected under authority of the State Dairy and Food Commissioner, the Commissioner of Agriculture or the State Board of Health. In no state, however, is there a

systematic inspection of all dairy herds, excepting in Massachusetts, where the inspection is made for the purpose of controlling bovine tuberculosis. A number of cities, on the other hand, require periodical inspection of the herds from which they obtain their milk supply. L. P.]

The control to which a number of large milk companies have submitted voluntarily, either from philanthropic motives or because driven to it by competition, consists chiefly in frequent, regular visits from veterinarians to the milk producing herds, during which not only the conditions of health of the cows but also their food, the cleanliness of the stables, the handling of the milk, and the health of the milkers are the objects of a more or less effective supervision. Some establishments have provided a separate organization for supervising the health of the employees. It is self-evident that the methods of such companies, however good their private supervision may be, must be subject to the superior control of health officers.

[It will be observed that the author dwells not so much on the importance of the recognition of infective organisms in milk as on their exclusion. *Unquestionably it is infinitely better, from the standpoint of the public health, to prevent the contamination of milk than, by means of laboratory examination, to discover evidences of contamination in a sample representing a quantity of milk that has already been consumed.*

Milk is not a food that is kept long; it cannot be put away in storage until a sanitary examination has been made, and then released for consumption, or destroyed, according to the result of the examination. Only the briefest inspections can be made while the milk is *en route* from the producer to the consumer.

The supply continues as a flowing stream, and is

never just alike at different times or places. The laboratory examination of a milk sample gives some information as to the condition of that sample and, by inference, as to the conditions under which a certain quantity of milk was produced and handled *on a given day.* But some of the contaminations of milk that are most dangerous cannot be detected by routine examinations in the laboratory, if at all, excepting by their effects on the consumer; among such contaminations are those caused by the specific organisms of tuberculosis, typhoid fever, diphtheria, scarlet fever and the *materies morbi* of many diseases of cows. Therefore, so far as the prevention of the infection or pollution of milk is concerned, it is more important that the milk be produced under such conditions that contamination is well guarded against than to know the condition of a certain quantity that has already been used.

The laboratory examination of milk is, however, of much value in checking and controlling the accuracy of farm and herd inspections, which inspections are designed to prevent infection and pollution, while the laboratory discovers contaminations that have already occurred.

The author's position on this general subject is quite analogous to the opinion that is now held by sanitarians in regard to the way in which the purity of the water supply should be obtained and insured; that is, by cleaning and guarding the source.

It is well to lock the stable door before the horse is stolen. But it has, thus far, been impossible in America, excepting in a few isolated instances, to impress the public sufficiently to lead to the establishment of a systematic inspection of the sources and methods of handling and transporting milk. Reasons for this condition are, the paucity of specially trained men for this ser-

vice and, on this account, the difficulty health officers have experienced in securing inspectors to do such work in a satisfactory way and, secondly, the expense. *A properly equipped dairy farm inspector must have had special training, and must be familiar with, and be able to apply, facts from pathology, bacteriology, zoötechnics and dairy husbandry.*

Dr. William T. Sedgwick has emphasized the importance of control of the source of the milk supply, to prevent pollution, as follows:[40]

"It should never be forgotten that if water were to be drawn, as milk is, from the body of a cow standing in a stable, by the hands of workmen of questionable cleanliness, and then stored and transported over long distances in imperfectly cleaned, closed cans, being further manipulated more or less, and finally left at the doors at an uncertain hour of the day, few would care to drink it, because its pollution and staleness would be obvious. It is clear, moreover, that it requires and deserves more careful treatment than water, for it is more valuble, more trusted and more readily falsified or decomposed."

Dr. Rowland G. Freeman has stated his opinion as to the importance of controlling the source of the milk supply, rather than to attempt to determine its character by bacteria counts, in these words: "It seems to me that while the counts of bacteria are exceedingly valuable as an exponent of cleanliness and proper handling of milk, they should be used only to prevent carelessness at the dairy and to stimulate better methods and discipline.

"The opinion of a milk commission of representative men (experts) based on an actual knowledge of the management of the dairy is of vastly more value to the

[40] Sedgwick, Principles of Sanitary Science and the Public Health. New York and London, 1902, page 279.

medical profession and to the public than any statement regarding the precise number of bacteria in the milk upon any given day or days. The most important things, after all, are such a régime as shall make contamination by pathogenic organisms improbable, and at the same time insure that the milk is produced under such conditions of cleanliness that other bacterial contaminations will be reduced to the minimum." L. P.]

a. **The condition of health of the herd.** The ideal requirement that only milk from a *perfectly healthy* herd may be marketed, cannot be maintained. The public, therefore, must be satisfied to demand that the health condition of the herd is such that its milk does not possess injurious qualities. If infectious diseases which are transmissible, through milk, to man, break out in the herd, the sale of the milk should be forbidden as long as danger of infection be present. If individual cases of infectious or other diseases occur which may lead to the contamination of the milk of the affected cows by pathogenic bacteria or toxins, it must be the duty of the owner to prevent this milk being mixed with the other milk, and, indeed, wholly to prevent its use as food for man.

Such regulations as the following may be regarded as necessary:

The use of the milk from the whole herd is to be discontinued if foot-and-mouth disease, lung plague or anthrax occur, also in the case of extended outbreaks of transmissible infections of the udder, septic enteritis, cowpox, or of any toxic disease of a large part of the herd.

The milk of individual cows should not be used, and affected animals are immediately to be removed from the stable, in cases of tuberculosis affecting the udder, the uterus or the intestines and when the lungs are so affected as to occasion physical symptoms; also, milk

from cows suffering from anthrax or rabies (bitten by affected animals), and that from cows with mastitis, with inflammation of the uterus and retention of the afterbirth, inflammation of the intestines or severe diarrhœa, and with severe cellulitis or abscesses and suppurating wounds.

Milk should not be used from cows suffering from any sort of febrile disease or intoxication, with pox or suppurating sores on the teats, with inflammation or other disease of the udder, constipation or diarrhœa. Moreover, it should not be used from cows that are being treated with medicines that have a strong odor (volatile oils, ether, asafœtida and the like), with alkaloids or potent glycosides, with preparations of iodine, arsenic, mercury, antimony or lead.

A very proper requirement is that *milk from cows that have recently calved is not to be mixed with the rest of the milk,* for the beast milk (colostrum) differs greatly in composition from normal milk and may have a harmful effect on small children. For 6 to 8 days after calving, the milk should not be mixed with the other milk. Also, *milk from cows approaching the end of the period of gestation and which are only giving a little milk, should not be mixed with that intended for sale,* because it is often quite alkaline and may differ a good deal in its composition from normal milk.

The complete observance of these requirements is, evidently, very difficult to control. In part, one must rely on the honesty of the owner, who should be held responsible for failure to comply with the legal requirements. When a dairyman is under contract to furnish milk to a company having its own conditions and regulations, he may be held accountable for failure to fulfil the obligations he has undertaken. In general, it can be

said that the observance of the conditions that are outlined above, as well as those that will be mentioned later, can be expected only when *the dairy farm is under the inspection of a veterinarian* who is entirely independent of the owner.

Therefore, when it is possible, one should endeavor strongly to arrange for such veterinary supervision. Naturally, it is of some advantage to make inspections now and then, at irregular times, but if the control is to be really effective, the visits must take place frequently, and with some degree of regularity. Preferably, the visits should not be more than fourteen days apart because, in that time, tuberculosis may attain such development that bacilli may be excreted with the milk, and diseases of the udder often develop acutely and follow a short and rapid course, thus making frequent examinations necessary. Only in cases in which the milk is subjected to a really safe process of pasteurization before it is sold, should a less frequent inspection be considered sufficient.

[This amount of supervision, a visit to each producing farm every two weeks, is not attainable with relation to the milk supply of the large cities of the United States, nor is it to be regarded, in the present provisional state of the sanitary development of the country, as necessary. That producing farms should be under some supervision, all agree. The amount of supervision that is necessary varies with the conditions. If a given herd is known to be infected with tuberculosis and infested with other diseases, if the premises are bad and the owner careless, then frequent inspections should be made until there is decided improvement; on the other hand, if a certain herd is known to be clear of tuberculosis, calf cholera, infectious gargets, etc., if the premises are good and well kept and the owner intelligent and

careful, longer intervals may safely be permitted to elapse between visits. After an inspector has gone over his ground and has become acquainted with local conditions, and the individuals, the question of frequency of visits should be left to a larger extent to him.

The number of inspectors required is of course in direct proportion to the frequency of inspections. If a single inspector could visit all of the dairy farms supplying a given city in one year, about twelve inspectors would be required to visit these farms each month. It is estimated that the number of inspectors that would be required to carry out an adequate system of dairy farm inspection for the city of Philadelphia is about 20. About 60 to 80 country inspectors would be required for the city of New York. L. P.]

For herds supplying "*nursery milk*" or "*infants' milk,*" decidedly rigid requirements must be made because, so far as possible, this milk must be so produced that it can be used in its raw state by children and invalids without any danger whatever.

Therefore, dealers should not be permitted to sell milk under these names if the herds are not under the inspection of a public veterinary officer; and the inspections should take place at least every fourteen days, preferably every week. It must be required that "nursery milk" shall come only from herds absolutely free from tuberculosis (*i.e.,* herds that are *tested with tuberculin at least once every year,* and to which only absolutely healthy animals are allowed to be added), because the diagnosis of some dangerous forms of tuberculosis is often very difficult and, in the earlier stages, even impossible, and because it has been proven impossible to prevent the occurrence of the dangerous forms merely by the removal of animals in which tuberculosis is clinically apparent. Besides, the definite requirement

must be made that the delivery of milk must cease instantly if numerous cases of septic enteritis or streptococcus mastitis appear and also if "calf cholera" occurs malignantly or endemically.

Moreover, the prompt removal from the herd is desired of every animal that has fever, or any kind of infectious disease. It is the duty of the owner himself to discontinue the delivery of the milk and to undertake the necessary isolation, when occasion may arise between the visits of the veterinarian, and he should call the veterinarian as soon as any suspicious disease may appear.

These requirements are already enforced by private companies and so there can be no question as to whether it is possible to carry them into effect but, up to the present time, they are enforced by the public in only a few cities.

b. **Feeding the herd.** As has already been stated, it is now the belief that the composition of the milk does not depend in any material degree on the composition of the food, and that injurious substances are not excreted through the udder to the extent that was formerly supposed. Therefore, one is not justified in forbidding the use of such a number of foods as has been done and is still done by some large cities. Only such foods should be prohibited as are decomposed (mouldy, putrid or fermenting), or materials containing great numbers of resistant bacteria of fermentation (creamery refuse, frozen forage, the offal of root crops, etc.), or excessive quantities of unnatural food materials (the refuse of some manufactories, distillers' slops, malt, molasses etc.), and strongly smelling vegetable matter (turnip tops, cabbage, green forage containing poisonous plants, etc.). The use of other food stuffs should be forbidden in such quantities as are injurious to the cow (turnips

causing diarrhœa, concentrated feed causing indigestion, poisoning by cotton-seed and nut-cake, etc.).

It has been required in some cases that cows supplying " nursery milk " shall be fed only upon dried fodder, and the use of oil meals has been restricted. By this means, milk has been obtained which is good and uniform, but it is so very expensive that its use is restricted. Our present knowledge of the effect of food upon milk does not sustain this requirement. But, it should be observed, the stable and cows can be kept clean much more easily if the cows are fed exclusively upon dry foods than when they are fed in part upon turnips or other green food. Therefore, if this one-sided method of feeding is not demanded, great emphasis must be placed on cleanliness with respect to herds supplying nursery milk. It is not inappropriate, however, to make some extra requirements in regard to feeding cows producing nursery milk. For example, food stuffs, such as distillers' slops, malt and molasses, as well as all fodder which, fed in large quantities, may be injurious to cows, should not be used (buckwheat, lupine, mustard, rape, cakes mixed with mustard, cotton-seed meal, nut-cakes, potatoes, etc.). Of course it is difficult to prove that a ration containing a small quantity of these materials would impart injurious properties to the milk; but it is safest, when it concerns milk for small children, to avoid any possible danger connected with the use of such foods; the more so, as this prohibition would have no influence at all upon the cost of production of the milk. Nor should one be allowed to give so great a quantity of turnips or green fodder to cows that are stabled that they suffer from diarrhœa, even to a slight degree.

[There has been much discussion and, in the past, much difference of opinion, as to the propriety of using

silage as a food for milch cows, and especially as food for cows producing nursery or certified milk.

The building of silos and the ensiloing of crops are new procedures in America, as elsewhere, and methods both of construction and filling have undergone rapid development. Only a few years ago, when square, poorly built silos were used, some of them built as pits, below ground, and before silage cutters and elevators had been developed, and when it was the practice in some cases to ensilo green maize stalks without cutting, and in bundles, there was much decomposed, putrid and mouldy silage, which had a very offensive odor and which was decidedly objectionable as food for dairy cows or, indeed, for any animals.

In these days, however, silos are better made and better filled; they are usually round or octagonal, thus facilitating even filling and settling, machinery for cutting has been perfected, so that the silage is divided into short lengths of from one-half to one inch, and Indian corn, the chief silage crop, is no longer used in the soft, immature state, but is permitted to come almost to maturity. Putrefaction does not occur in properly handled silage. The fermentation that takes place is caused partly by bacteria and partly by enzymes in the maize plant. Good silage is a wholesome, nutritious food that is appetizing and comparatively easy of digestion.

Silage is fed to cows on nearly, if not quite, all of the large farms in America devoted to the production of certified and nursery milk. It is not known to be subject to any objection other than if fed in too large quantity it produces an undesirable degree of laxativeness, and if fed just before or during milking, if it is not first class, the odor of the silage may be eliminated with or absorbed by the milk. This is avoided by feeding it after

milking and by not allowing the residues to accumulate in or about the stable.

Frasier [41] has shown by some tests made with milk from cows fed silage of good quality that no objectionable flavor or odor was imparted to the milk either when the silage was fed before, during, or after milking. Indeed, in 372 tests made, silage milk was preferred in 233, or 60 per cent. L. P.]

A further demand in reference to herds supplying nursery milk should be established—that frequent and sudden changes in food should be forbidden, as the composition of the milk immediately after such a change is often materially altered, and it is more probable that when the udder is "surprised" by such a sudden change the secretory function is thrown out of equilibrium and abnormal, and possibly injurious, substances are secreted with the milk.

c. **Cleanliness in the stable and during milking.** In order to guard, so far as possible, during milking, against pollution with dirt and, at the same time, with bacteria, the most thorough cleanliness of the cows and the stable, and care on the part of the milkers, is to be desired. However, it is very difficult to establish detailed regulations in this respect, and no less difficult to enforce them. We usually find that the regulations under this heading are confined to the concisely stated orders that cows and stables must be kept clean; that, at milking, the greatest possible cleanliness must be observed and that, just before milking, the udder and teats are to be washed.

However, where the conditions permit the establishment of more detailed regulations, as in the larger milk

[41] Wilber J. Frasier, Bulletin No. 101, Agricultural Experiment Station, University of Illinois, Urbana, 1905.

companies, which are under private control, this should be done. In this connection, the following regulations which, first, the Copenhagen Milk Supply Company and, afterward, other companies in Copenhagen, have furnished to their producers stand as an example to be imitated:

1. The stable must be so built that the urine has an unobstructed exit and the floor must be of such nature that it may easily be kept clean. The cows must be well bedded and, for this purpose, no spoiled or rotten straw or hay can be used, nor straw or hay that has previously been used for packing. The stable must be kept as clean as possible. In the morning, the manure must not be removed until after milking; in the afternoon, at least one hour should pass after mucking out before milking. After cleaning the stable, it should be thoroughly aired, unless the ventilating system is particularly good, so as to render this unnecessary.

2. In order to prevent the hind quarters of the cow from becoming too dirty, the hair of the tail, on the udder, the flanks and on the outer side and the rear of the thighs should be clipped before the cow is stabled in the fall. Besides this, the cow should be cleaned with a curry comb and brushed every day. Definite and more stringent regulations concerning the cleanliness of the stable and the cows should be made in summer, if they are fed in the stable, and in winter if green (laxative) fodder is used.

3. When the cows are kept in the stable, their teats are to be washed with clean water and dried with a clean cloth. If the udder is dirty, this, also, must be washed and dried. If the cows are milked in pasture, this cleansing cannot be done so satisfactorily [and there is less occasion for it], so it is usually best to confine the washing of the teats and udder to such of the cows

as are apparently soiled with manure or earth. If there are sores upon the teats these must be carefully washed off. Instead of washing, one may rub the udder with a dry cloth or brush it and then rub in a little neutral fat [as vaseline].[42]

4. The milkers must have a special dress to be used only during milking, and this must be washed as often as necessary. The milkers must wash their hands before milking, and during milking they must have plenty of clean water and clean cloths at hand with which to wash not only the teats but also their own hands, as often as is necessary.

5. Milk pails, milk strainers and milk cans must be carefully cleaned in the dairy house. If it be necessary to rinse out the pails or strainers when milking in the pasture, only clean water which has been carried to the place must be used and not that from a reservoir in the pasture.

d. **The health of the attendants.** A very important point in milk hygiene is the condition of health among the workers in the dairy and of the milkers and, indeed, among all persons who are connected with milk production. As has already been emphasized, there are a number of infectious diseases of man which can easily be transmitted through milk and which have appeared in many instances as extended "milk epidemics." Frequent inspection by a physician of all persons connected

[42] [This reference to milking cows at pasture, which has now become unusual in most parts of America, is explained by the Danish custom of keeping cows tethered out of doors the entire summer. During this season, the cows are allowed to graze on grass and especially planted forage crops, which are harvested by the cows without waste, as the tether pin to which the tie rope is attached is moved but a few feet at a time and is not moved again until the forage within reach has been consumed. Water is carried to the cows in tanks on wagons. L. P.]

with the business is scarcely feasible, both because it would be an expensive procedure and because, in most cases, it would meet with great opposition and tend to increase labor difficulties.

But the following regulations are regarded as necessary and they should be incorporated in public ordinances:

The sale of milk shall cease immediately if typhoid fever, scarlet fever, diphtheria, or other malignant infectious disease breaks out among people living in the farmstead;[43] the sale shall not be resumed until a physician's certificate has been received showing that all danger of infection is over.[44]

Care must be taken that the milk does not come in contact in any way with persons in whose household one of the above-mentioned diseases exists, nor those who have discharging sores or skin diseases of the arms, hands or face.

In addition, the local authorities should have the right to forbid the sale of milk if this is known, or believed, to be the cause of an epidemic, even though no source of infection be proven on the farms in question.

Several of the large milk companies of Copenhagen have established even more rigid regulations in regard to the health of the personnel and they insure the enforcement of these rules by allowing the producer full value for his milk, when he holds it back on account of the occurrence of disease. The value of such a provision is obvious.

c. **The water supply.** Since typhoid bacteria (and

[43] [The farmer's residence and the cow stable adjoin, so that they are, practically, parts of the same building, on most of the small farms of Denmark.]

[44] [The danger of infection from persons recovering from typhoid fever and diphtheria continues for a long time.]

other pathogenic bacteria) may gain access to milk through water used to wash the milk vessels, care must be taken that pure water be provided on the farms from which market milk is sold, and that polluted or infected water is not used for cleansing the dairy utensils, nor the udder, nor shall it be used for the cows. [Contaminated water has also done harm when used for cooling milk and it is believed to have led to the infection of milk, indirectly, through the soiling of the skin of the cow, as when wading through a foul stream. L. P.]

f. **The care of the milk.** Immediately after milking each cow, the milk must be run through a fine metal strainer into a container. The strainer holds back only the larger pieces of dirt and some of these are dissolved by the continuous pouring of the milk, and bacteria are washed through, so it is advisable, so far as possible, to prevent the dirt that has been removed from coming into contact with the milk that is to follow. But it cannot be said that a strainer has yet been made that solves this problem in a satisfactory way; therefore one must get along by frequently cleansing the strainer from the particles of dirt. Of course, it is very difficult to insure the observance of such a stipulation. Sufficiently rigid requirements in regard to the cleanliness of the milk sold and the seizure of impure milk, followed, perhaps, by the imposition of a fine would aid in enforcing the regulation.

After the milk is drawn, it must be carried to a place prepared for this use and which must be used for no other purpose. This room must be well ventilated, clean and have an impervious floor.

The milk must be cooled as soon as possible by passing it over a cooler or by putting the cans into tanks containing ice water. If it is nursery milk, the cooling must be very carefully done, so that the temperature

may not exceed 10° C. (50° F.). Milk should be kept chilled until it is ready to be shipped and then it must be guarded carefully against high temperature by protecting it from the sun, transportation by night, etc.

If the transportation of milk requires a long time, it must be cooled to a low point, and, while it is not well to allow the whole quantity to freeze, in recent years a partly frozen milk (the outside layer frozen in the cans) or the addition of frozen milk to the other milk have been successfully used.

[Milk shipped long distances in America is sent in refrigerator cars. Some milk is on the railroad 10 hours before it reaches market. Milk shipped short distances is usually not sent in refrigerator cars because, on the short runs, the cars have to be opened so often at local stations that there would be a great consumption of ice. If such milk is thoroughly chilled by the use of ice before it is shipped, it usually arrives in good condition; but if it is cooled only by the use of well or spring water it is an uncertain commodity in the hottest weather. Bottled milk is shipped in wooden boxes with broken ice packed around the bottles.

Helm [45] has proposed that milk shall be shipped in square, instead of round, cans, so that they may be packed more closely and thus make a solid block, of low temperature, which may be covered over if necessary, and which will remain cold much longer than a loose collection of round cans, between which the warm air may freely circulate. This style of can is shown in figure 14. L. P.]

Only well-tinned metal cans which are easily cleaned should be used for keeping milk (Fig. 13); these should be closed and sealed when transported by rail or boat.

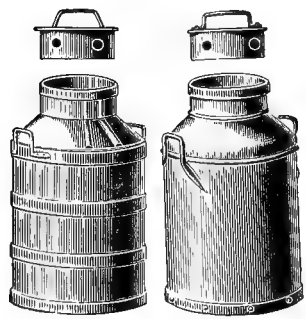
[45] Wilhelm Helm, Die Milchbehandlung, Liepzig, 1903.

II. REGULATIONS CONCERNING THE SALE AND DELIVERY OF MILK

Just as supervision is necessary of the herds which produce the milk, and in regard to the care of milk at its source, so also is supervision necessary after it comes into the hands of the wholesale and retail dealers. This supervision is much easier to carry out than that with relation to production.

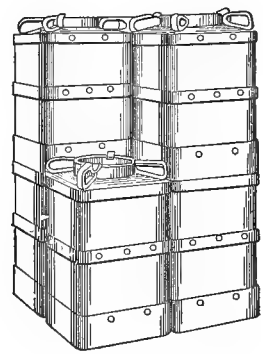
The regulations governing sale and delivery must embrace not only the methods of handling the milk and

FIG. 13.



Danish milk-cans.

FIG. 14.



Helm's milk-cans.

the health of the attendants, but there should also be rules concerning the place in which the milk is sold, the manner of selling it and the labelling of the goods.

a. **Preparing the milk for delivery.** Although small concerns subject the milk to no especial treatment from the time it is received until it is sold, this is not the case with the large companies. These have considerable work to perform in the handling of milk and its delivery to customers. The milk [under the Danish system] is received from the stations in a more or less cool condi-

tion and the cans are put into ice water in order to chill the milk sufficiently. It is then poured into a tank and mixed, thus making its composition uniform. Then follows a process of cleansing, wherein the milk is either passed through a centrifuge, so constructed that the cream and the milk are not separated, but only particles of dirt are thrown out, or it is passed through a filtering apparatus which holds back some of these particles. A gravel filter is frequently used for filtering. This is a tank which is filled with layers of gravel of different degrees of fineness, through which the milk is slowly forced. The gravel is cleansed daily by washing and roasting. Only the particles of dirt are removed by this process; the number of bacteria is not appreciably reduced. A filter made of numerous layers of fine linen, tightly stretched, has been used successfully instead of the gravel filter. The cloth part is renewed after each use. This method has, among others, the advantage that the filtering may take place directly into the can from which the milk is drawn off for sale, or the apparatus may be so arranged that while the milk is being filtered and run off, it is at the same time cooled.

The " clarified " milk is put into metal cans or glass bottles in which it is to be sold. This filling is sometimes done automatically, so that incorrect measuring is not possible, and sometimes by means of a machine similar in construction to those used in filling beer bottles.

If the milk is to be pasteurized, it is first filtered, then run through the pasteurizer and over the cooler, into the delivery can; or it is placed in the clean bottles or cans that go into the pasteurizer or sterilizer (see page 139).

The public will scarcely require ordinances containing exactly detailed regulations in regard to these different processes. Generally it is required only that the

vessels and apparatus used shall be entirely clean, that the milk be handled with the greatest cleanliness and be kept in well-tinned metal cans or in glass or earthenware vessels with perfect glazing, containing no lead, and that all vessels shall be so constructed that they will not be difficult to clean.

Special regulations should be established for the pasteurization of milk. If the heating is of short duration, it is desirable that the milk be heated to 80° C. (176° F.) and cooled immediately afterward. The following requirements should be established for heating at a lower temperature: Milk should be raised to a temperature of 65° to 70° C. (149° to 158° F.) and held there for one-fourth hour or it should be kept for one-half hour at a temperature of 60° to 65° C. (140° to 149° F.). The pasteurizer should be known to act accurately enough to attain the required temperature with certainty.

b. **The places for keeping and selling milk.** The places in which milk is handled must be light, airy and easy to keep clean; therefore, they must be provided with an impervious floor and a good drain, and good, pure water must be easily accessible.

The salesplaces must likewise be bright, airy and clean and, in addition, there are a number of special requirements. Milk should not be allowed to be sold in the same shop with other goods, with the exception of certain foods (as bread, honey, flour, butter, margarin and eggs), which cannot, either by their odor or in any other way, have a deleterious influence on the flavor and the keeping quality of the milk. Conducting a laundry, or a similar business, in the same place in which milk is kept or handled, should not be permitted. Of course, the apartment must not be used as a dwelling or a sleeping room, and it should not be in direct communication with sleeping rooms. If the place used for keeping and

selling milk is in communication with living rooms, as happens in small premises, then it is positively necessary to have the apartments separated by a thick door, which shall be kept closed.

c. **The condition of health of the attendants.** The same rules that apply to attendants in the places of production should be binding upon those at the salesplaces. However, as the enforcement of these rules naturally meets very great difficulties, in most cities action has been limited to making the regulation and then punishing those guilty of offences that are, by chance, discovered.

Several large concerns (*e.g.,* some in Copenhagen) have voluntarily enforced strict regulations in regard to the health of attendants. In order to be sure that no suspicious disease among them or in their households shall escape being reported, they provide free medical services and also pay full wages to every employee who is temporarily absent from his work on account of illness in his family. (Compare regulations governing the producers for this society, page 178, and Appendix I, page 241.)

Moreover, the public health department of the government must be authorized—possibly upon the payment of indemnity—to close milk businesses for a longer or shorter time, which are known to spread contagion, even though it cannot be shown just where the infection comes from. This authority must also apply to milk shops, when cases of typhoid fever, scarlet fever or diphtheria exist among people who work with the milk. If it is proven that the infection did not occur in the shop, the milk and the cream may be sold after sterilization, if care is taken to see that this is thoroughly done. A milk shop is to be kept closed as long as there is danger that it may distribute infection.

d. **Marking and packing the milk.** The requirements

in respect to marking milk for sale form quite an important part of the regulations on the handling of milk, because these have a very important bearing on the prevention of adulteration. The kinds of milk and milk products which are of importance are whole milk, "half milk," skim milk, cream and buttermilk.

Whole milk is the usual name for normal cow's milk which has not been deprived of any of its fat or other ingredients. As the fat content of milk is far from being uniform, and as partial skimming, or the addition of skimmed milk, is, therefore, not easily detected, many attempts are made to deceive by these falsifications. In order to prevent the sale of milk that may be unadulterated but which is too poor in fats, and in order to lessen the number of adulterations, a minimum content of fat and solids has been established in many cities, as well as the limits of the specific gravity. Milk which does not contain the required amount of fat cannot be sold as whole milk; if it is so sold it is considered adulterated.

Reinsch [46] has made a comparison of these requirements in the German cities. Among 63 ordinances, 60 contain such a minimum limit for fat; 37 of these place the limit at 2.7 per cent., 5 at 2.4 per cent. to 2.5 per cent., 7 at 2.8 per cent., 9 at 3 per cent. and only 2 have established a higher minimum at 3.2 per cent. to 3.3 per cent. In 19 ordinances, the minimum content of solids varies between 10.5 per cent. and 12 per cent.; most require 11 per cent. to 11.5 per cent. Twenty-five place the limits of specific gravity; 10 of these as 1.028 to 1.034, 8 as 1.029 to 1.033 and 5 as 1.029 to 1.034, while a single one provides 1.027 to 1.034.

[The German standards are low because the fat content of the milk of some of the breeds of dairy cows

[46] Die gesetzliche Regelung des Milchverkehrs in Deutschland, Hamburg, 1903.

in Germany is very low. It would be quite impracticable to enforce higher standards under such circumstances.

In 26 states of the United States there are laws establishing milk standards.[47] The limits for fat are from 3 per cent. (in one state only is the limit below 3 per cent.; in Rhode Island it is 2.5 per cent.) to 3.5 per cent. (in one state, Massachusetts, for half the year, the limit is 3.7 per cent.). For total solids, the limits are from 12 per cent. (in one state only is the standard lower: Ohio, during May and June, it is 11.5 per cent.) to 13 per cent.

The standards for cities and towns vary within the same limits; some are established by the state standard and some by the cities themselves. L. P.]

It is evident from the above requirements that it is difficult to agree on percentages and standards which may be considered perfectly just and reasonable. If the requirements are placed too high, the owners of a number of herds (especially those made up of purchased cows) soon find it impossible to deliver milk in the cities; if the requirements are placed too low, the object of regulation is attained only to a very limited extent. Therefore, it has been suggested that different grades of whole milk be established. Leipzig and Dresden have such a provision, under which only milk with a minimum fat content of 2.8 per cent. to 3 per cent. is permitted to be sold as "whole milk I quality," while unadulterated cow's milk of less fat content can be sold under the name "whole milk II quality"; in Leipzig, however, this can be marketed only with the designation of the fat content. Several other Saxon cities have similar

[47] H. E. Alvord and R. A. Pearson, The Milk Supply of 200 Cities and Towns, U. S. Dept. of Agr., B. A. I., Bulletin No. 46, Washington, 1903.

provisions, under which milk containing less than 2.8 per cent. fat can be sold only with a definite statement of the fat content.

It must depend upon local conditions whether such a provision is desirable or not, and also whether it is regarded as wise to establish a minimum fat (and solid) content, and at what point these should be placed.

[Legal standards for milk are, by some, objected to on two grounds; first, that it is unfair to establish a minimum standard so high that it will exclude the milk from some cows, and, second, that if the standard is low it will encourage dealers to dilute rich milk to a point just above the standard.

As to the first objection, it does not appear to be unreasonable that an article of food sold as milk shall be required to contain a certain minimum amount of nutriment. Entirely aside from the adulteration of milk, which such standards are established to check, it is possible to select and develop herds of cows of certain breeds that will furnish milk of very low fat and solids—not fat content. What has occurred in this direction is shown by reports on the weekly analyses of the milk of a herd of cows at Jaschkowitz,[48] where the milk ran down to 2.47 per cent. fats and 7.88 per cent. solids not fat. The lowest average for the herd for a month was: fat, 2.60 per cent.; solids not fat, 8.06 per cent.; total solids, 10.66 per cent. The official records of Holstein cows[49] show that many individuals yield milk containing less than 3.0 per cent. of fat, and some as little, for a time at least, as 2.6 per cent. This tendency could, undoubtedly, be intensified if the absence of milk stand-

[48] Bericht über die Tätigkeit des Milchwirtschaftlichen Instituts zu Proskau für das Jahr 1905–1906.

[49] C. B. Lane, Record of Dairy Cows in the United States, U. S. Dept. of Agr., B. A. I., Bulletin No. 75, Washington, 1905.

ards favored it. In other words, the milk could be watered through the cow. The tendency among breeders of Netherland cattle in America (and largely on account of milk standards) is to increase the fat content of their milk, and many such cows yield milk containing 4 per cent. to 4.5 per cent., and, exceptionally, even 5 per cent. of fat.

In regard to the second objection, the dilution of rich milk is scarcely more likely to be practiced if there is a minimum standard than if there is none, and it can be prevented quite as effectively by law, inspection and penalty with a minimum standard, as without one.

All of the existing standards in the United States are much below the average quality of the milk sold in the cities to which the standards apply. It is proposed by Wing[59] that no special standard be established, but that each dealer be required to guarantee his own standard, and that he be held responsible if his milk be found below this guarantee. Some dealers now sell bottled milk of different grades, containing either 4 per cent. or 5 per cent. of fat, but all of it is above the minimum standard. L. P.]

Special rules must be made for milk sold under the name "*infants' milk*" or "*nursery milk*," and it must be required that this shall come absolutely from herds that are under constant veterinary inspection and whose condition of health and cleanliness and feed are governed by special requirements (see page 174). In a number of German ordinances, in addition to these requirements, the minimum fat content is placed at 3.0 per cent., which is considered fair. [In the United States "Certified milk" is usually required to contain 4 per cent. fat.] Another regulation which is justly put upon

[59] H. H. Wing, Milk and its Products, New York and London, 1899.

the dealer in nursery milk is that the milk shall be sold only in clear glass bottles and that the bottles shall be cleansed or sterilized before they are filled.

It should be required that milk sold as "*controlled*" ("*certified*" or "*guaranteed*") shall come from herds that are under constant and competent veterinary inspection.

Half skimmed or "*half milk*" is milk from which a part of the fat has been removed. It is well to establish a minimum fat content of 1 to 1.5 per cent., as already has been done in some German cities.

[In most cities in America, milk that is below the minimum standard, as half skimmed milk is, can be sold legally only as skimmed milk. There is no grade for milk between whole milk and skimmed milk. The desirability of establishing such a grade may well receive careful consideration. The same end could be gained by the adoption of Wing's suggestion, but its enforcement would entail administrative difficulties. L. P.]

[*Skimmed milk* is milk from which the cream has been removed by hand skimming or from which the butter-fat has been extracted by means of a centrifugal separator. The former kind may contain from 0.5 per cent. to 1.5 per cent. fat, while the latter rarely contains more than 0.3 per cent. fat and sometimes as little as 0.01 per cent. The sale of skimmed milk is wholly prohibited in some American cities, as in New York. This prohibition is placed on account of the great inclination on the part of some dealers to sell skimmed milk as whole milk and the difficulty of detecting and preventing this practice. It is possible, however, to secure a proper observance of the law on this subject, as is proven by the experience of cities in all countries, and it would be far better for the rich City of New York to employ more inspectors, if necessary, to prevent fraud

in the sale of skim milk than to deprive the poor of this wholesome, nutritious and cheap food.

It should be required in every case that vessels containing skim milk shall be permanently and conspicuously marked. To deliver or to store skimmed milk in an unmarked container on the premises or wagon of a dealer should be regarded as evidence of intent to defraud and should subject the violator to penalty.

Skimmed milk should contain not less than 9.25 per cent. of milk solids. L. P.]

Cream, for the production of which the same sanitary requirements are necessary as for milk, should be sold with the fat content designated, if there is no local regulation to grade it or establish fat percentages. [The percentage of fat in cream varies from 8 per cent. to 50 per cent., or more. The usual quality, as sold in the market, contains about 15 per cent. to 20 per cent. fat. The standard for cream, as established by the U. S. Department of Agriculture, is 18 per cent. Heavy, rich cream contains from 30 per cent. to 40 per cent. fat. L. P.]

[*Buttermilk* requires no special standard except that it be made from clean milk, and in a cleanly way. It is largely used as a summer beverage and, as typhoid bacilli and other pathogenic forms will live in it for some time, it is important that it be protected from contamination. An imitation of buttermilk is sometimes made in city milk shops by churning sour skimmed milk. L. P.]

Pasteurized milk. The following regulations are proposed for milk that has been heated and that is to be sold as " pasteurized ": Under this name, and without a more detailed statement, should be understood milk that has been heated to at least 80° C. (176° F.); if the milk is pasteurized at a lower temperature, this must be

distinctly marked upon the bottle or can, and the milk must not be permitted to go upon the market until the method has received official sanction. *Sterilized milk* should be sold only with a statement of the way in which sterilization has been done, and not until after the method has been inspected and approved. But it is not enough merely to establish such requirements; the sanitary officers must see to their enforcement, partly by visiting the pasteurizing and sterilizing establishments, partly by taking samples and examining the milk sold. Fortunately, it is possible to determine by chemical means whether milk has been heated to 80° C. (176° F.) or not. These tests are based on an observation by Arnold and have been developed by Babcock, Storch and others.[51] The principles are the following:

Storch's method: 5 c.c. of milk are poured into a test tube; a drop of weak solution of hydrogen dioxide (about 0.2 per cent.), which contains about 0.1 per cent. sulphuric acid, is added, and 2 drops of a 2 per cent. solution of paraphenylendiamin, then the fluid is shaken. If the milk or the cream becomes, at once, indigo blue, or the whey violet or reddish brown, then this has not been heated or, at all events, it has not been heated higher than 78° C. (172.5° F.); if the milk becomes a light bluish gray immediately or in the course of half a minute, then it has been heated to 79° to 80° C. (174.2° to 176° F.). If the color remains white, the milk has been heated at least to 80° C. (176° F.). In the examination of sour milk or sour buttermilk, lime water must be added, as the color reaction is not shown in acid solution.

Arnold's guaiac method: a little milk is poured into a test tube and a little tincture of guaiac is added, drop by drop. If the milk has not been heated to 80° C. (176° F.), a blue zone is formed between the two fluids; heated milk gives no reaction, but remains

[51] Heating milk to a high temperature coagulates the albumin and globulin and the milk loses its property of curdling by the action of rennet. By this change one may discover that it has been heated, but not determine whether the milk has been heated to 80° C. (176°F.), that is, if it has been pasteurized.

white. The guaiac tincture should not be used perfectly fresh but should have stood a few days and its potency have been determined. According to the observations by Glage, the guaiac-wood tincture appears to be more reliable than the harz tincture. Zink recommends the addition of a few drops of weak solution of hydrogen dioxide, as this causes the reaction to be much surer and sharper.

Of the two methods, the guaiac method is preferable in that the tincture is very lasting and may be kept a year without becoming ineffective, while the paraphenylendiamin solution must be renewed quite often; on the other hand, the guaiac method is, perhaps, hardly so accurate as the Storch method.

Other substances are useful as reagents in combination with hydrogen dioxide, as solution of potassium iodide with starch (Storch, du Roi, Köhler and others) and ursol (Utz); besides these, a methylene-blue-formalin solution (Schardinger) has been suggested for this purpose.

[Storch's test may also be used for the purpose of detecting the adulteration of fresh milk with diluted condensed milk. In this case it is well to make the test comparative by running a parallel sample of milk known not to have been heated. L. P.]

The sale of *milk preparations* which are made either by using foreign additions or by some special manipulation of the milk should be permitted only when the milk has been produced under the requirements above stated and only on declaration of the composition of the preparation.

Milk containers. In case the milk is retailed in containers, there should be some stipulation in regard to these. Metal cans should be of tinned iron; for tinning, no tin should be used that has more lead than is absolutely necessary; the form must be such that they can be easily cleaned. Bottles are to be made of clear glass so that every impurity is noticeable; their form must, likewise, make satisfactory cleansing possible.

In recent years, the large milk companies have en-

deavored in their own interest, as well as in that of the public, to provide sealed stoppers or covers for delivery bottles and cans, which more surely prevents their being opened before delivery and which makes it impossible for an unscrupulous person to fill anew, with milk or cream, the vessel which, from accident or improper reasons, was partly or wholly emptied. With metal cans, this security is most easily effected by the use of a simple lead and wire seal, applied after filling. A perfectly reliable closure for the bottles, on the other hand, offers some difficulty, because it is so expensive. The accompanying illustrations show some of the methods used. Fig. 15 shows a method of closing which corresponds to that used on mineral-water bottles. After closing, a label is pasted over the top; this method is somewhat expensive and does not furnish a satisfactory guarantee as the label is easily loosened. Fig. 17 shows

Fig. 15.

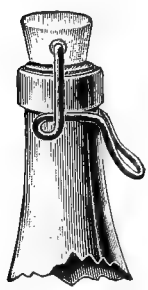


Fig. 16.

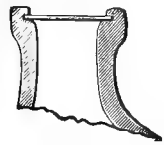
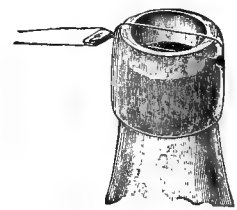


Fig. 17.



the method used by the " Trifolium " milk company in Copenhagen. The upper part of the neck is perforated, and after the bottle has been closed by the insertion of the stopper, a wire is drawn through the holes and secured with a lead seal; this method gives efficient protection but is somewhat expensive. Fig. 16 shows a method used during recent years in Germany, which is cheap and quite satisfactory. In the inside of the neck

there is a small groove; after the bottle is filled, it is closed with a paraffined pulpboard cap which is pressed down into the neck of the bottle by means of a stamp, with its edges in the groove; at the same time, the cap is marked, and it cannot be taken out without being torn. A similar cover, a pasteboard cap which is pressed a little way into the bottle (without the groove), is used by many milk concerns, but this gives little security, as the cap can easily be taken out and a new one substituted.

[Paper or wood-pulp discs (sterilized) used as stoppers may be sealed by pouring on top of them a little melted paraffine. This method is used by some dairies that produce certified milk. The customary method, however, among the best dairymen, is to cover the top of the bottle, after it is closed with the usual disc, with a cap of parchment paper, held around the neck of the bottle with a wire, cord or rubber band; or a cap of heavy tin foil is used, which is pressed down around the shoulder at the mouth of the bottle, and this holds its position quite well. Both of these methods have the advantage of thoroughly guarding the mouth of the bottle and the disc that confines the milk. The lip of the bottle, over which the milk must be poured, is prevented from becoming soiled. These methods, however, do not afford such complete protection against tampering with the contents of the package as is furnished by a lead seal. However, if the box in which the bottles of milk are shipped from the farm to the distributing point, or to the customer, is sealed with a lead seal, as is done by some producers, the protection is sufficient.

The usual practice among average dairymen is to depend on unparaffined and unsterilized wood-pulp discs, upon which is often printed the name of the dealer.

Small dealers (and some large ones as well) sometimes indulge in the most vicious and unsanitary prac-

tices in regard to bottling milk. They pour milk into bottles from cans in their wagons or hand carts on the street, exposing it to dirt, and, worst of all, they sometimes fill bottles that have not been cleaned, or that have not been properly cleansed. Milkmen have been known to take a soiled bottle from the house of a customer, fill it with milk on a dirty wagon, while the wind is blowing dust about, close it with a disc taken from a coat pocket, perhaps from alongside a handkerchief, and then deliver it in the next house. It is not surprising that it has been seriously proposed to prohibit the use of milk bottles. But the bottling of milk marks a distinct sanitary advance, where it is carried out in a proper manner. It should be provided by public regulation that milk shall be delivered in bottles only under the following conditions:

1. Before they are filled, bottles shall be washed and sterilized, or they shall be cleansed by the use of some method that has the approval of the sanitary authorities.

2. Stoppers for the bottles shall be clean (preferably sterilized) and shall be kept only in sterile packages or in a clean metal or glass receptacle provided exclusively for this use.

3. Bottles shall be filled with milk only in a clean room provided for this purpose, and they shall not be removed from this room until they are stoppered. L. P.]

III. PUBLIC SUPERVISION TO PREVENT ADULTERATION

Just as many foods can be adulterated, so also can milk and cream. As the fat is the most valuable ingredient of milk, a common adulteration consists in partial skimming, or in the addition of skimmed milk or water; less frequently, foreign material is added to the milk in order to give it a better appearance. It can be only excessively rarely that gross adulterations occur, such as the one reported by Sullivan, wherein a sample of

"milk" was found to consist of a mixture of water, white pigment, common salt and a little skimmed milk.

There is no general rule as to the frequency of adulteration. In some cities, it does not appear to be particularly frequent, while in others it is very common.

Besides the adulterations found upon official examinations of the market milk in cities, the question of fraud sometimes arises in connection with the milk delivered to creameries. In the creameries, it is customary to use some quick method for determining the approximate fat content of the milk that is delivered by the various patrons.

In the official control of milk in cities two provisional or preliminary tests have long been used and these are still depended on to some extent; they consist in the determination of the specific gravity and in a test of the transparency. Even when used in conjunction, these tests are not to be relied upon very far, but they can be used, if with sufficient caution, to determine whether a more thorough examination be necessary. If it is decided that a laboratory examination is required, a sample should be taken with great care, and sealed and delivered to the appropriate expert for analysis.

The specific gravity of cow's milk varies between about 1.027 and 1.040 at 15° C. (60° F.); but such differences are to be found only in the milk of certain individual cows. The specific gravity of mixed-herd milk usually falls between 1.028 and 1.034. If the specific gravity is either above or below these limits it is always suspicious. [The average specific gravity is 1.032.]

Many different forms of apparatus have been proposed for measuring *the transparency of milk,* to determine if it is or is not diluted. However, these instruments are all defective and the results obtained by their use are not to be regarded as of any value except to indi-

cate whether a sample of the milk should be taken for analysis. The transparency of milk is dependent partly on the size and number of the fat globules, and partly on the casein in solution. As milk with fewer, but large, fat globules has not the same transparency as milk with more, but smaller, ones, even if the fat per cent. be the same, it is evident that these methods of examination may give misleading results.

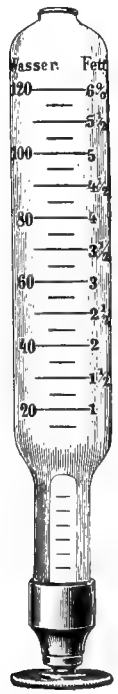
Feser's lactoscope is the simplest and best instrument made for this purpose. As Fig. 18 shows, it consists of a glass tube which narrows toward the bottom and is closed with a metal cap which supports a short vertical glass column on which are six black lines; the upper part of the glass has divisions marked with a double row of figures. Four c.c. of milk to be examined are poured into the tube, then enough water is added so that it will reach figure 40 (that is, 36 c.c. of water); the fluid is now mixed by shaking. If it is not possible to see the lines on the glass column inside the tube, a little water is added and the tube is again shaken; this is continued until the lines become visible. When they can be seen through the diluted milk, the fat per cent. can be read from the scale. For example, if so much water has been added that the fluid reaches figure 60 (60 c.c. water and milk), then the milk has 3 per cent. fat. As already stated, this result cannot be relied upon; in the examination of skimmed milk, quite too high a percentage of fat is always indicated and, in regard to whole milk, the test may show from 0.5 per cent. to 1 per cent. too much or too little.

On account of the unreliability of this method in many places this preliminary test is no longer used and the inspectors take samples, without preliminary inspection, for examination in the laboratory.

[In the use of the lactoscope, the individual coeffi-

cient is of great moment. Different inspectors will interpret the same result quite differently. When one is experienced in examining with the lactoscope the milk of a given breed of cows, he may become so proficient that he can make a fair estimate of the fat content, but

FIG. 18.



Feser's Lactoscope.

FIG. 19.

Quevenne's Lactodensimeter.

when another kind of milk is examined the result may not be so accurate. If milk tests normally, *both* in respect to specific gravity and lactoscopically, it is not apt to be much skimmed or watered.

The following is from Leach:[52]

[52] A. E. Leach, Food Inspection and Analysis. New York, 1905.

"As in the case of the lactometer, the purity of a milk sample cannot be positively established by the lactoscope alone. For instance, a watered milk abnormally high in fat would often be found to read within the limits of pure milk, when as a matter of fact its solids would be below standard. By a careful comparison of the readings of both the lactoscope and the lactometer, however, it is rare that a skimmed or watered sample could escape detection.

"Thus, if the specific gravity by the lactometer is well within the limits of pure milk, and the fat, as shown by the lactoscope, is above 3¼ per cent., the sample may be safely passed as pure, or as conforming to the standard.

"A normal lactometer reading in connection with an abnormally *low* lactoscope reading shows both watering and skimming, and with an abnormally *high* lactoscope reading shows a milk high in fat, or a cream. With the lactoscope reading below three, and a low lactometer reading, watering is indicated. A lactometer reading above thirty-three, and a low lactoscope reading, indicate skimming." L. P.]

IV. METHODS OF EXAMINATION

In order to determine whether adulteration has taken place or not, the examination should cover the following: The specific gravity of the milk and of the whey, the fat content of the milk, the amount of milk solids, the amount of solids not fat, the specific gravity of the solids, the quantity of fat [and the percentage of ash]. Sometimes, the examination is extended to include the taking of a herd sample under special conditions in order to make a comparison between the sample officially collected and the milk offered for sale. Finally, foreign ingredients are tested for, as nitrates, starch, [preservatives, artificial color, "viscogen," gelatin, etc.].

a. **Taking samples for laboratory examination** must be conducted with great care. Upon standing, the cream quickly rises to the top, so that the upper part of the milk contains more fat, even though no definite layer of cream has yet been formed. Therefore, before the test

is made, the milk should be well mixed. In milk that has been thoroughly chilled, it is difficult to again mix the cream equally, so one must be very exact in taking the sample. It often happens, in the milk shops, that the milk is not well mixed when sold and an examination of what is left may show so low a percentage of fat that one immediately becomes suspicious that adulteration has taken place, although it may not be so.

b. **Preserving the sample for analysis.** If the milk sample is to be kept or shipped, it is necessary to add a preservative. For this, potassium dichromate ($\frac{1}{2}$ grm. to 1 liter) is used, which keeps the milk fluid for a long time; this addition causes an increase in the specific gravity and the result of the chemical examination is also affected. This must be taken into consideration at the final test. It is generally better to add 20 drops of formalin to every liter, yet in this case it is possible that the specific gravity of the whey may be affected, on account of a partial splitting of the casein. It is still better to boil the filled bottle and then close it with a sterilized cork. In taking the sample, it is also necessary to avoid adding water even in the slightest quantity (rinse the bottles with milk), in order that no nitrate shall be added.

c. **The herd sample.** In cases in which adulteration is suspected, comparison may be made of the milk under suspicion with that of the herd milked under supervision. The importance of the stable, or herd test has been much overestimated. The great variations in the composition of the milk of individual animals, leads one to be careful in putting confidence in a comparison of the fat content of milk on different days; but comparisons may fairly be made between the quantities of solids not fat and the specific gravity of the whey, which are fairly regular. The stable or herd test is very uncertain, therefore, for individual cows, or small herds, but it may

sometimes be used with advantage for large herds, although there is seldom cause, even in this case, to apply it.

In taking a herd sample, the feeding and the care of the animals should not be varied in any respect, the milking should be conducted by the usual persons at the usual times and in the usual way; less thorough milking gives lower fat content, while particularly thorough milking raises the percentage of fat. The quantity of milk for the day must be mixed together and the sample taken from the whole. As transitory changes occur in the composition of the milk, surer results will be gained from daily examinations for several days than from but one examination.

d. **Determining the specific gravity of milk and whey.** Various instruments are used for this purpose: different areometers, the pycnometer or the hydrostatic scale. The areometer method is the simplest and, at the same time, it is sufficiently accurate, so there is no occasion to describe more in detail the other methods, which require weighings.

Quevenne's lactodensimeter, in some one of its several modifications, is the areometer in common use. This is made like an ordinary areometer and divided into degrees which correspond to a specific gravity from 1.014 to 1.040, or only from 1.022 to 1.038, since, by the latter division, a greater space is gained between the different degrees, without unduly lengthening the instrument. From such a lactodensimeter one can easily read off four decimal places.

The milk whose specific gravity is to be determined is well shaken and poured into a high glass cylinder of suitable diameter; the areometer is dropped in slowly, in order to prevent its bobbing up and down. [The bulb should be free from adhering air bubbles.] The figures

on the stem are the second and third decimals of the numbers of the specific gravity, so that 34 is to be read 1.034. For this examination, the temperature of the milk must be 15° C. (60° F.); if it is not, the specific gravity of the milk at 15° C. must be calculated from the specific gravity found and from the temperature, for in milk inspection and analysis this is the standard. With the aid of the tables on pages 204 and 205, one of which is valid for whole milk and the other for skimmed milk, one can easily compute specific gravity for 15° C. from that found at another temperature.

If the temperature of the whole milk is 18° C., and the lactodensimeter reads 29, one finds in the table, at the intersection of the perpendicular column 18° C. and the horizontal line 1.029, the number 29.6; the specific gravity is therefore equal to 1.0296 at 15° C. (See tables, pages 204 and 205.)

In several of the lactodensimeters (*e.g.*, Soxhlet's) there is a thermometer in the instrument, whose scale does not show the degree of heat but gives directly the decimal to be added to or subtracted from the reading on the stem of the lactodensimeter, as the specific gravity. If the latter number is, for example, 29, and if the thermometer registers 3.5 above zero, the specific gravity at 15° C. is 1.02935.

[The so-called New York Board of Health lactometer has an arbitrary scale divided into 120 equal parts. One hundred on this scale corresponds with a specific gravity of 1.029, which was supposed to represent the lowest specific gravity of pure milk, and 0 represents 1.000, the specific gravity of water. If the specific gravity of a sample of milk fell to 90 it was supposed to be 90 per cent. pure, that is, to contain 10 per cent. of added water. But the specific gravity of milk varies so that this cannot be relied on and there is no single advantage

TABLE FOR CORRECTING THE SPECIFIC GRAVITY OF **WHOLE MILK** ACCORDING TO TEMPERATURE.

Specific Gravity.	Temperatures Centigrade.														
	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
1.019	18.1	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	19.0	19.1	19.3	19.5	19.7	19.9
1.020	19.0	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.8	20.0	20.1	20.3	20.5	20.7	20.9
1.021	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.0
1.022	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0
1.023	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.0
1.024	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.0
1.025	23.8	23.9	24.0	24.1	24.2	24.3	24.5	24.6	24.8	25.0	25.2	25.4	25.6	25.8	26.0
1.026	24.8	24.9	25.0	25.1	25.2	25.3	25.5	25.6	25.8	26.0	26.2	26.4	26.6	26.9	27.1
1.027	25.8	25.9	26.0	26.1	26.2	26.3	26.5	26.6	26.8	27.0	27.2	27.4	27.6	27.9	28.2
1.028	26.7	26.8	26.9	27.0	27.1	27.2	27.4	27.6	27.8	28.0	28.2	28.4	28.6	28.9	29.2
1.029	27.6	27.7	27.8	27.9	28.1	28.2	28.4	28.6	28.8	29.0	29.2	29.4	29.6	29.9	30.2
1.030	28.5	28.6	28.7	28.8	29.0	29.2	29.4	29.6	29.8	30.0	30.2	30.4	30.6	30.9	31.2
1.031	29.5	29.6	29.7	29.8	30.0	30.2	30.4	30.6	30.8	31.0	31.2	31.4	31.7	32.0	32.3
1.032	30.4	30.5	30.6	30.8	31.0	31.2	31.4	31.6	31.8	32.0	32.2	32.4	32.7	33.0	33.3
1.033	31.3	31.4	31.6	31.8	32.0	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.7	34.0	34.3
1.034	32.2	32.3	32.5	32.7	32.9	33.1	33.3	33.5	33.8	34.0	34.2	34.4	34.7	35.0	35.3
1.035	33.1	33.2	33.4	33.6	33.8	34.0	34.2	34.4	34.7	35.0	35.2	35.4	35.7	36.0	36.3
	42.8°	**44.6°**	**46.4°**	**48.2°**	**50.0°**	**51.8°**	**53.6°**	**55.4°**	**57.2°**	**59.0°**	**50.8°**	**62.6°**	**64.4°**	**66.2°**	**68.0°**
	Temperatures Fahrenheit.														

TABLE FOR CORRECTING THE SPECIFIC GRAVITY OF **SKIMMED MILK** ACCORDING TO TEMPERATURE.

Specific Gravity.	Temperatures Centigrade.														
	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
1.023	22.3	22.3	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.4	23.6	23.8
1.024	23.2	23.2	23.2	23.3	23.4	23.5	23.6	23.7	23.9	24.0	24.1	24.2	24.4	24.6	24.8
1.025	24.1	24.1	24.1	24.2	24.3	24.4	24.5	24.6	24.8	25.0	25.1	25.2	25.4	25.6	25.8
1.026	25.1	25.1	25.1	25.2	25.3	25.4	25.5	25.6	25.8	26.0	26.1	26.3	26.5	26.7	26.9
1.027	26.1	26.1	26.1	26.2	26.3	26.4	26.5	26.6	26.8	27.0	27.1	27.3	27.5	27.7	27.9
1.028	27.1	27.1	27.1	27.2	27.3	27.4	27.5	27.6	27.8	28.0	28.1	28.3	28.5	28.7	28.9
1.029	28.1	28.1	28.1	28.2	28.3	28.4	28.5	28.6	28.8	29.0	29.1	29.3	29.5	29.7	29.9
1.030	29.0	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.8	30.0	30.1	30.3	30.5	30.7	30.9
1.031	30.0	30.0	30.1	30.2	30.3	30.4	30.5	30.6	30.8	31.0	31.2	31.4	31.6	31.8	32.0
1.032	31.0	31.0	31.1	31.2	31.3	31.4	31.5	31.6	31.8	32.0	32.2	32.4	32.6	32.8	33.0
1.033	32.0	32.0	32.1	32.2	32.3	32.4	32.5	32.6	32.8	33.0	33.2	33.4	33.6	33.8	34.0
1.034	32.9	33.0	33.1	33.2	33.3	33.4	33.5	33.6	33.8	34.0	34.2	34.4	34.6	34.8	35.0
1.035	33.8	33.9	34.0	34.1	34.2	34.3	34.4	34.6	34.8	35.0	35.2	35.4	35.6	35.8	36.0
1.036	34.8	34.9	35.0	35.1	35.2	35.3	35.4	35.6	35.8	36.0	36.2	36.4	36.6	36.9	37.1
1.037	35.8	35.9	36.0	36.1	36.2	36.3	36.4	36.6	36.8	37.0	37.2	37.4	37.6	37.9	38.2
1.038	36.8	36.9	37.0	37.1	37.2	37.3	37.4	37.6	37.8	38.0	38.2	38.4	38.6	38.9	39.2
1.039	37.7	37.8	37.9	38.0	38.2	38.3	38.4	38.6	38.8	39.0	39.2	39.4	39.6	39.9	40.2
1.040	38.6	38.7	38.8	38.9	39.1	39.2	39.4	39.6	39.8	40.0	40.2	40.4	40.6	40.9	41.2
	42.8°	44.6°	46.4°	48.2°	50.0°	51.8°	53.6°	55.4°	57.2°	59.0°	60.8°	62.6°	64.4°	66.2°	68.0°

Temperatures Fahrenheit.

in this arbitrary scale, which is very confusing. Unfortunately, however, it has come into rather general use among milk inspectors, especially in the Eastern States.

To convert readings of this lactometer into corresponding readings of the Quevenne scale, they must be multiplied by 0.29, or, the following table may be used:

QUEVENNE LACTOMETER DEGREES CORRESPONDING TO NEW YORK BOARD OF HEALTH LACTOMETER DEGREES.

Board of Health Degrees.	Quevenne Scale.	Board of Health Degrees.	Quevenne Scale.	Board of Health Degrees.	Quevenne Scale.
61	17–7	81	23–5	101	29–3
62	18–0	82	23–8	102	29–6
63	18–3	83	24–1	103	29–9
64	18–6	84	24–4	104	30–2
65	18–8	85	24–6	105	30–5
66	19–1	86	24–9	106	30–7
67	19–4	87	25–2	107	31–0
68	19–7	88	25–5	108	31–3
69	20–0	89	25–8	109	31–6
70	20–3	90	26–1	110	31–9
71	20–6	91	26–4	111	32–2
72	20–9	92	26–7	112	32–5
73	21–2	93	27–0	113	32–8
74	21–5	94	27–3	114	33–1
75	21–7	95	27–6	115	33–4
76	22–0	96	27–8	116	33–6
77	22–3	97	28–1	117	33–9
78	22–6	98	28–4	118	34–2
79	22–9	99	28–7	119	34–5
80	23–2	100	29–0	120	34–8

L.P.]

Specific gravity of the whey. In many cases it is of value to determine the specific gravity of the whey because this is much more constant than that of milk, for the reason that the lactose and salt vary less than the fat.

Lescoeur warms the milk to 45° C. (113° F.) and adds rennet; after about one-half hour the whey is pressed out and filtered, then it is cooled to exactly 15° C.; the specific gravity may then vary between 1.029 and 1.031, but if water has been added it decreases significantly, as shown below:

Whey of pure milk	= 1.0300
Whey of milk + 10 per cent. water	= 1.0275
Whey of milk + 20 per cent. water	= 1.0251
Whey of milk + 30 per cent. water	= 1.0230

Reich recommends that 20 c.c. glacial acetic acid be added to 500 c.c. milk, that the mixture be well shaken and heated for 5 to 6 minutes to 60° to 65° C. (140° to 150° F.) in a closed flask, then cooled and filtered; the filtrate is to be heated in a flask until the albumin coagulates, then filtered again and the specific gravity determined after cooling to 15° C. According to his results, this varies between 1.027 and 1.029; a specific gravity of 1.026 is always a sign of the addition of water.

If one wishes to apply the determination of specific gravity of whey to milk inspection, it is necessary to develop a definite method, which must be followed out exactly, for, otherwise, the result is uncertain; and before basing a prosecution on the results of this method, one must have made careful comparisons, with the same method, of normal and watered milks.

From investigations that were undertaken in Copenhagen under Jensen's direction, it appears that these two methods do not give uniform results. From 35 milk samples the following results were obtained:

Rennet method			Acid method		
		Specific gravity			Specific gravity
7	samples	1.0270 to 1.0274	2	samples	1.0257 to 1.0259
7	"	1.0275 to 1.0279	10	"	1.0260 to 1.0264
15	"	1.0280 to 1.0284	15	"	1.0265 to 1.0269
6	"	1.0285 to 1.0290	8	"	1.0270 to 1.0276

The addition of water causes a lower specific gravity of the whey. In the examination of adulterated skimmed milk, he found the figures to be 1.0256, 1.0246, 1.0254 and 1.0257 (rennet method) and 1.0242, 1.0234, 1.0238 and 1.0241 (acid method).

e. **The determination of the fat content of milk.** There are many methods for determining the fat content of milk; some of these are too inexact to be considered (*e.g.,* the above mentioned transparency test by means of the lactoscope, and the like), others give very good results but require rather expensive apparatus, still others require exact weighings and work that can be done only in chemical laboratories. Some simple tests are, however, so accurate and so practical that they are available for the work of milk inspection.

Among the methods used, besides the transparency test already mentioned, the creamometer should be named, that is, the measurement of the layer of cream which rises when the milk is allowed to stand. Since, however, the thickness of the layer of cream furnishes no reliable gauge as to the fat content, this method cannot be used if there is to be a prosecution. The separation of the cream by a centrifuge of high velocity (Fjord's test), and subsequently measuring the layer of cream, gives better results and is often used in creameries for comparing milks. For general use, however, it is impractical, and not sufficiently accurate.

The available methods are, principally, Soxhlet's method, which was formerly used to a greater extent than it is now; Gerber's method, [the Leffmann-Beam and the Babcock methods] and methods of chemical analysis.

Soxhlet's method is founded upon the following principle: the solution of the fat in ether and the determination of the specific gravity of this solution.

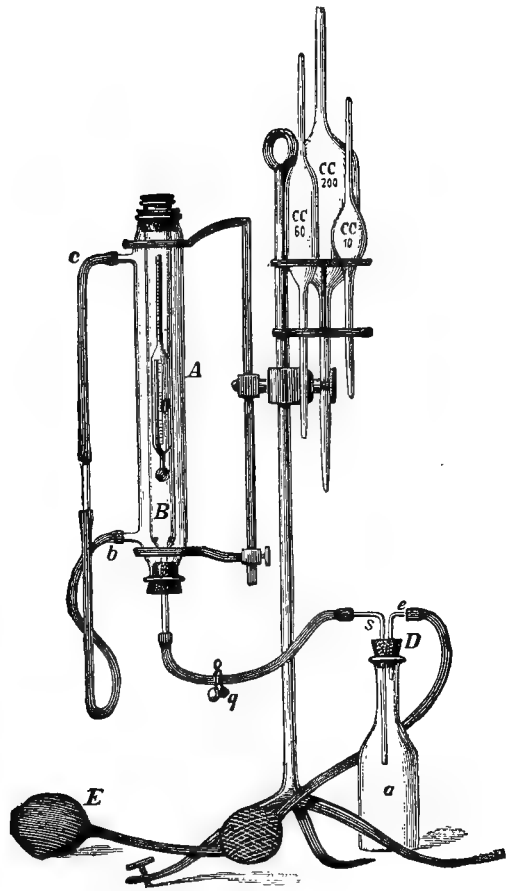
The following appliances are necessary for this examination (see Fig. 20): (1) three pipettes of 200, 60 and 10 c.c.; (2) several half liter bottles; (3) two delicate areometers with thermometer, one for whole milk and the other for skimmed milk; (4) one large glass tube (A) adjusted for flowing water; (5) a smaller glass tube (B) enclosed in A; (6) a rubber bulb with a tube; (7) a larger container filled with water heated to 17° to 18° C. Besides these, the following chemicals are necessary: (8) potassium hydroxide solution of specific gravity 1.27 (400 gr. potassium hydroxide is dissolved in water and after the solution has cooled it is made up to 1 liter); (9) ether, shaken with one-fifth its volume of water and decanted off; (10) ordinary ether.

The milk to be examined is warmed in a water bath to 18° C. and is well shaken. By means of a pipette, 200 c.c. of this are drawn off and mixed in a bottle with 10 c.c. of the potassium hydroxide solution. Then, 60 c.c. of ether are added. The bottle is immediately closed by a perfectly tight stopper, is violently shaken and allowed to stand one-fourth hour in water at 18° C., during which time it must be shaken frequently. Gradually, the ether dissolves the fat and a transparent layer is formed on the surface. Now the stopper of the bottle is replaced by another (D) and, by means of a bulb, the transparent fat-containing ether is driven up into the tube B which is surrounded in tube A by water warmed to 18° C. The areometer (C) is in the inner tube, and after the fluid rises so high that it can float, the flow is checked by means of a valve q, then the specific gravity is read. The quantity of fat dissolved is shown, and from this the fat content of the milk can be calculated. Soxhlet's apparatus is accompanied by tables from which the fat content of the milk can easily be read, if one has determined the specific gravity of the fat-ether, and has read its temperature.

Gerber's acidobutyrometer affords a very convenient and accurate way of determining fat, that is widely used. The method consists in measuring the quantity of fat in an accurately measured quantity of milk, after the fat has been separated and dissolved in amyl-alcohol. Gerber's instrument (see figs. 21 and 22), consists of a centrifuge, bottles (G) of special shape, and 3 pipettes, *i.e.*: 1 acid pipette to hold 10 c.c. (H) and 2 small pipettes (I, K) of 1 and 11 c.c. capacity. These chem-

icals are required: crude sulphuric acid of a specific gravity at 15° C. (60° F.) of 1.825, and amyl-alcohol. The examination is made in the following way: 10 c.c.

FIG. 20.

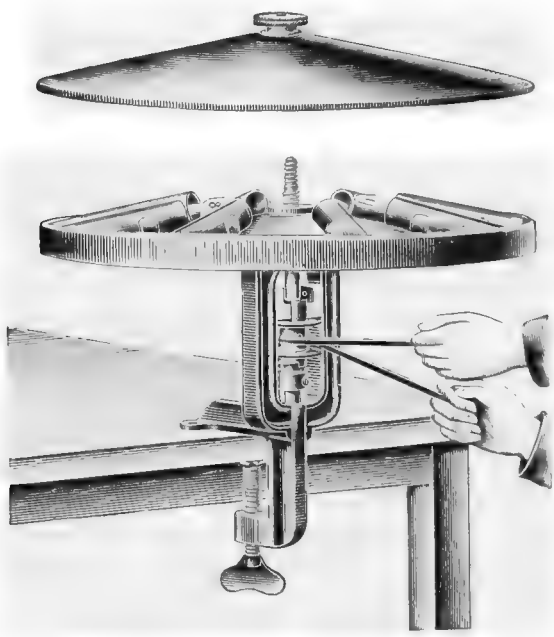


Soxhlet's apparatus for fat-determination.

of sulphuric acid are measured out by the acid pipette, this is permitted to flow slowly into the bottle G; 1 c.c. of amyl-alcohol is measured and poured carefully into

the glass so that it forms a layer upon the surface of the sulphuric acid. Now, exactly 11 c.c. of well mixed milk that has been heated to 15° C. (60° F.) are measured and poured into the bottle, which is closed by a rubber stopper and then it is well shaken. The milk dissolves with the generation of considerable heat. The stopper is driven in so far that in the inverted bottle, the fluid

FIG. 21.

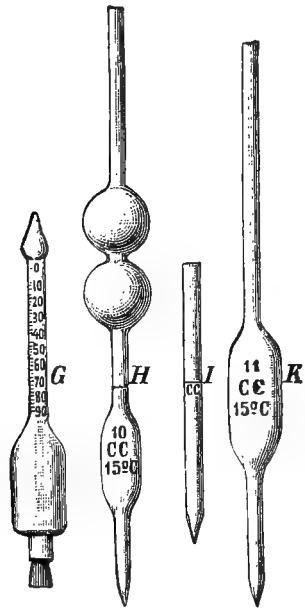


Gerber's apparatus for fat-determination.

reaches the mark 0 on the scale; the bottle is put into the centrifuge and this is set in motion, after it has been well balanced. If the sample is not to be centrifuged at once, the bottle should be placed in a water bath at 60° to 65° C. (140° to 150° F.). The process of centrifuging lasts 10 minutes with such a machine as shown in figure 21; and in order to keep up speed it is necessary to ac-

celerate the motion three times, by drawing the strap. [With some patterns of centrifuge, those that have a velocity of 800 to 1000 per minute, the whirling is completed in 3 to 4 minutes.] After centrifuging, the bottle is taken out and placed in a water bath at 60° C. (140° F.). The fat forms a clear layer in the top of the tube. Through shifting the stopper, the lower border of the

FIG. 22.



Test bottles and pipettes used in connection with Gerber s method for fat-determination.

fat layer can be brought into the same plane with one of the division lines and the thickness of the layer of fat can be read off. One should read from the lower part of the curved upper line. The upper, narrow part of the tube is divided in 90 parts, each line corresponds to 0.1 per cent. fat; for example, if the fat layer reaches line 35, then the fat content of the milk is 3.5 per cent.

[*The Leffmann-Beam method* (sometimes, improperly, called the Beimling test) was worked out in advance of the Gerber test, which resembles it. The following description is from Leffmann:[53] "The distinctive feature is the use of fusel oil, the effect of which is to produce a greater difference in surface tension between the fat and the liquid in which it is suspended, and thus promote its readier separation. This effect has been found to be heightened by the presence of a small amount of hydrochloric acid.

"The test bottles have a capacity of about 30 c.c. and are provided with a graduated neck, each division of which represents 0.1 per cent., by weight, of butter fat.

"Fifteen c.c. of the milk are measured into the bottle, 3 c.c. of a mixture of equal parts of amyl-alcohol and strong hydrochloric acid added, mixed, the bottle filled nearly to the neck with concentrated sulphuric acid, and the liquids mixed by holding the bottle by the neck and giving it a gyratory motion. The neck is now filled to about the zero point with a mixture of sulphuric acid and water prepared at the time. It is then placed in the centrifugal machine, which is so arranged that when at rest the bottles are in a vertical position. If only one test is to be made, the equilibrium of the machine is maintained by means of a test bottle, or bottles, filled with a mixture of equal parts of sulphuric acid and water. After rotation for from one to two minutes, the fat will collect in the neck of the bottle and the percentage may be read off. It is convenient to use a pair of dividers in making the reading. The legs of these are placed at the upper and lower limits respectively of the fat, allowance being made for the meniscus; one leg is

[53] Henry Leffmann, Analysis of Milk and Milk Products. Philadelphia, 1905.

then placed at the zero point and the reading made with the other. Experience by analysts in various parts of the world has shown that with properly graduated bottles the results are reliable. As a rule, they do not differ more than 0.1 per cent. from those obtained by the Adam's process, and are generally even closer.

" The mixture of fusel oil and hydrochloric acid seems to become less satisfactory when long kept. It should be clear and not very dark in color. It is best kept in a bottle provided with a pipette, which can be filled to the mark by dipping. Rigid accuracy in the measurement is not needed."

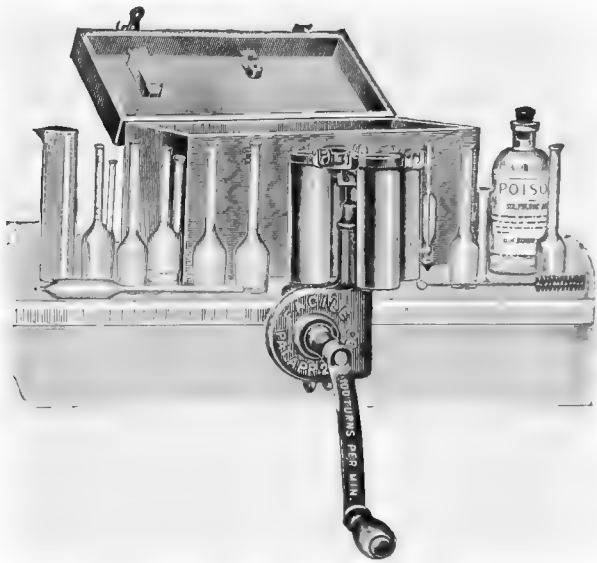
The Babcock method or " test " is, in America, by far the best known and most used centrifugal test for fat in milk. The Leffmann-Beam and the Gerber tests are, however, being used more and more, on account of the shorter time required.

In careful hands, the Babcock test is very accurate. Small or large outfits, the centrifuges to be driven by hand or power, may be purchased from any dairy supply establishment. The test is made by placing in the special test bottle 18 grams (17.6 c.c.) of milk. To this is added, from a pipette, burette or measuring bottle, 17.5 c.c. commercial sulphuric acid of a specific gravity of 1.82 to 1.83. The contents of the bottle are carefully and thoroughly mixed by a rotary motion. The mixture becomes brown and heat is generated. The test bottle is now placed in a properly balanced centrifuge and whirled for five minutes at a speed of from 800 to 1200 revolutions per minute. Hot water is then added to fill the bottle to the lower part of the neck, after which it is again whirled for two minutes. Now, enough hot water is added to float the column of fat into the graduated portion of the neck of the bottle, and the whirling is repeated for a minute.

The amount of fat is read while the neck of the bottle is still hot. The reading is from the upper limits of the mensicus instead of the lower, as with the Gerber and the Leffmann-Beam tests. A pair of calipers is of assistance in measuring the column of fat. L. P.]

The chemical methods consist in accurately weighing the fat separated from a definite quantity of milk. The

FIG. 23.



One form of Babcock's apparatus for fat-determination.*

most exact result is gained by the evaporation of a definite amount of milk (see below) and by the extraction of the fat from the evaporated mass by ether or benzine, which is then evaporated. Quite accurate results are also gained without evaporating the milk, by separating

* From "Principles and Practice of Butter-Making," by McKay and Larsen, by permission of Messrs. John Wiley & Sons, the publishers.

the fats from the other ingredients and ascertaining their weight.

Gottleib's method gives results sufficiently accurate for our use. For this method one requires, as apparatus, only a cylinder of 40 c.c. capacity, divided to measure quantities of 0.5 c.c., some glass flasks and a long, thin glass syphon. 10 grm. of milk are accurately weighed into one of the small flasks and poured into the glass cylinder; the amount of milk left adhering to the walls of the flask is determined by a second weighing, so that one may know exactly how much has been poured into the cylinder. 1 c.c. of 10 per cent. ammonia water (specific gravity 0.96) is mixed with the milk and shaken, then 10 c.c. alcohol (95 per cent.) are added and it is shaken again, after which 25 c.c. ether are added. The cylinder is well closed with a cork that has been moistened in water, and shaken hard. 25 c.c. petroleum benzine are added and, after repeated shaking, the bottle should be allowed to stand undisturbed at least 6 hours. By that time, the fluid is separated into two sharply marked layers; the upper one is the ether-benzine-fat mixture, the under one contains the water, the lactose and proteids; a whitish sediment consists of phosphates. The volume of the upper layer of the fluid is read off and a determined quantity of it is syphoned off into a small weighed flask. The ether and benzine are now evaporated by mild heat. Thereupon, the flask is allowed to stand a couple of hours in a drying chamber at 100° C., is cooled in an exsiccator and, finally, weighed. From the total volume of the mixture of ether, benzine and fat, and from the quantity of fat in the portion evaporated, the weight of the total fat content of the milk sample can be calculated, and thus the percentage is determined.

f. **Determination of the total solids in milk.** The total solids in milk are determined chemically in the following way: Exactly 10 c.c. of milk are measured into a platinum or porcelain vessel, the weight of which is already known; the vessel is heated in a water bath to 100° C. until all the water is evaporated. After cooling in an exsiccator, the vessel and its contents are weighed. The difference between the weight found and the original weight of the dish gives the total amount of solids in the milk. If the amount of fat, found in another way, is

subtracted, one gets the quantity of solids not fat. By incinerating the contents of the vessel, in a muffle oven, and again weighing, the amount of salts, or ash, is determined. If it is desired to extract the fat from the other solids, to determine the fat percentage, it is necessary before drying the milk to mix with it a weighed quantity of roasted pumice stone; then, after evaporation, the fat is removed by means of ether (or benzine) in an ordinary fat extraction apparatus, and is determined by weighing, after evaporating the ether. This work is quite particular and requires a well appointed laboratory. Moreover, in practical milk control, gravimetric analyses are not indispensable, for one can easily *calculate the quantity of solids from the specific gravity and the fat,* according to the formula derived by Fleischmann. If total solids are represented by t, the fat per cent. by f and the specific gravity by s, one has:

$$t = 1.2 \times f + 2.665 \frac{100s - 1000}{s}$$

That is, if we say $f = 3.55$ and $s = 1.0327$, we get

$$t = 1.2 \times 3.55 + \left(2.665 \frac{100 \times 1.0327 - 1000}{1.0327}\right) = 4.260 \frac{2.665 \quad 3.27}{1.0327} = 12.697$$

Another formula proposed by Bertschinger gives quite accurate results:

$$t = \frac{5f + 100s}{4} + 0.07$$

Moreover, tables have been worked out from which the total solids can be read off, if both the other factors are known. Ackermann has constructed an " automatic reckoner " from which one can read off one of the factors when both of the others are known, by simply turning circular discs. [Richmond has devised a sliding rule for the same purpose.]

The computation of the solids not fat is very easy.

One has only to subtract the fat percentage found from the computed percentage of total solids. The percentage of fat (p) in the total solids is easily computed according to the formula:

$$p = \frac{f}{t} \times 100$$

To use the above illustration:

$$p = \frac{3.55}{12.697} \times 100 = 27.95$$

Likewise, it is quite easy to determine *the specific gravity* (m) *of the dry milk solids* by a simple computation, according to this formula:

$$m = \frac{st}{st - (100s - 100)}$$

Using the same illustration again:

$$m = \frac{1.0327 \times 12.697}{1.0327 \times 12.697 - (103.27 - 100)} = \frac{13.112}{13.112 - 3.27} = 1.332$$

The specific gravity of the dry solids of whole milk varies, according to the fat content, between about 1.31 and 1.36.

V. ADULTERATION AND ITS DETECTION.

The most frequent adulterations of whole milk consist in partial skimming, dilution with skimmed milk, dilution with water or a combination of these. Skimmed milk is adulterated by the addition of water, and cream by starch, flour, etc.

a. **Partial skimming of whole milk or dilution with skimmed milk** produce the same result; in both cases the fat content is lessened, while the percentage of solids not fat is increased very slightly, and the specific gravity is increased. If the skimming is not so great as to cause the fat percentage to fall below the minimum limit for

mixed milk and the specific gravity to rise above its maximum (1.034), this adulteration is difficult to discover, as the considerable variations in normal milk would lead one to expect. It is in these cases that comparison was formerly made with the stable or herd samples, but, as stated before, these are worth but little in relation to small herds, and even in the case of large ones they are not entirely trustworthy. When it is possible to compare the figures of inspected milk with the results of the herd test, an opinion can be formed as to how great a percentage of the fat content is lacking, from this formula:

$$x \quad 100 \cdot \frac{F \div f}{F}$$

in which F shows the fat percentage in the herd sample and f the fat percentage of the sample under suspicion.

Where there is reason for suspicion, the best method for proving the existence of such adulteration is, in many cases, furnished by the judicial hearing of the persons charged, and the witnesses. In many places, as has already been stated, to prevent such adulterations a minimum standard has been established for the fat content of whole milk.

[In America, where there are legal standards calling for 3 to 3.5 per cent. of fat in whole milk, prosecutions for partial skimming or dilution with skimmed milk are not often brought if the sample comes up to this established standard, although such adulteration may be suspected from a marked disproportion between the fat and the solids not fat. But this proportion is, at best, so variable that it furnishes no definite guide. L. P.]

b. **The dilution of whole milk with water** causes an increase of volume and, therefore, a decrease in the percentage of fat, of solids and of the specific gravity of the

milk, as well as of the whey. Feser gives the following example:

Start with 9 liters of milk of the composition: 3.95 per cent., fat; 8.9 per cent., solids not fat; 1.031, specific gravity.

To this add 1 liter of water of this composition: 0 per cent., fat; 0 per cent., solids not fat; 1.000, specific gravity.

This gives 10 liters of adulterated milk of the composition: 3.55 per cent., fat; about 8.0 per cent., solids not fat; 1.028, specific gravity.

Further evidence of this adulteration is found in the lower specific gravity of the whey and in the fact that the specific gravity of the dry solids (m) and the fat content (p) of the solids are, practically, normal; in the above example, then:[54]

$$M = \frac{ST}{ST - (100S - 100)} = \frac{1.031 \times 12.85}{1.031 \times 12.85 - (100 \times 1.031 - 100)} = \frac{13.24}{10.14} = 1.305$$

$$m = \frac{st}{st - (100s - 100)} = \frac{1.028 \times 11.55}{1.028 \times 11.55 - (100 \times 1.028 - 100)} = \frac{11.873}{9.073} = 1.307$$

$$P = \frac{F}{T} \times 100 \qquad \frac{3.95}{12.85} \times 100 = 30.738$$

$$p = \frac{f}{t} \times 100 = \frac{3.55}{11.55} \times 100 = 30.736$$

If milk samples are available which may be justly compared with the milk under suspicion (herd samples taken under fixed conditions; milk from the same large herd; other milk sent by the same shipper or from the same can in the dealer's possession), then the percentage of water added can be computed according to Vogel's formula:

$$x = \frac{F}{f} \times 100 \div 100$$

[54] [M and P represent the specific gravity of the total solids and the percentage of fat in the total solids of whole milk, and m and p the same factors in adulterated milk.]

In the example just given we have F = 3.95 and f = 3.55, then

$$x = \frac{3.95}{3.55} \times 100 \div 100 \quad 11.11\%$$

that is, exactly 1 part to 9 parts. On account of the great variations in the percentage of fat, one must be very careful with this computation.

In detecting this adulteration, the herd sample is of some value, since the solids not fat are subject only to slight variations. In drawing conclusions, therefore, these other factors must have full consideration (estimated solids not fat, specific gravity of the whey), and are of more value as a guide than the percentage of fat.

[The percentage of solids not fat should not be less than 8.5 or 9. The percentage of ash is of considerable value in detecting adulteration by adding water. This factor is rather constant, and in pure milk is usually between 0.70 and 0.75 per cent. L.P.]

It has been suggested that use be made of the determining of the freezing point of milk and of its conductibility for electricity, since these qualities are considerably changed by the addition of water. But these methods are not yet sufficiently developed to be available. On the other hand, there may be some advantage in determining the acidity of the milk, since this is lessened by dilution (see page 227), yet the lessened acidity may come from other causes.

The addition of lactose or cane sugar to milk diluted with water, renders judgment more difficult, since, by this means, the specific gravity of the milk as well as that of the whey, and also the amount of solids not fat, is increased.

While milk is always free of *nitrates and nitrites*, even if the animals have taken such substances with

their food, these are frequently present in water in small quantity. The presence of nitrates or nitrites in the milk, therefore, shows, with certainty, that water has been added. However, the lack of nitrates does not exclude this, as all water does not contain nitrates. Even a very small quantity of nitrates and nitrites can be detected as follows:

1.5 c.c. of a 20 per cent. calcium chloride solution is added to 100 c.c. of milk; the mixture is boiled and filtered. A little of the filtrate is mixed with enough of a 2 per cent. solution of diphenylamin in sulphuric acid to make it milky; a little concentrated sulphuric acid is poured into a test tube and the mixture is added slowly, so that the fluids do not mix; if nitric acid or nitrous acid is present, a blue zone is formed at the plane of contact. (Soxhlet.)

[A simpler test for nitrates is that devised by Richmond. The following description of this test is from Farrington and Woll.[55] "Place a small quantity of diphenylamin at the bottom of a porcelain dish, and add to it about 1 c.c. of pure, concentrated sulphuric acid; allow a few drops of the milk serum (obtained by adding a little acetic acid to the milk and warming) to flow down the sides of the dish and over the surface of the acid. If a blue color develops in the course of ten minutes, though it may be faint, it shows the presence of nitrates, after ten minutes a reddish-brown color is always developed from the action of the acid on the serum. There should be no difficulty in detecting an addition of 10 per cent. of water to the milk by this test, if the water added contained 5 parts of nitric acid, or more, per 100,000." L. P.]

c. **The skimming of whole milk in conjunction with the addition of water,** or the addition of skimmed milk as well as water, are common methods of adulteration. It is easily understood that the fat content is considerably lessened in this way, and that also the solids not fat decrease; it is evident, besides, that the percentage of solids not fat (p) is lessened and, consequently, the

[55] Farrington and Woll. Testing Milk and its Products, 13th edition. Madison, 1904.

specific gravity of the solids (m) must be increased. The specific gravity of adulterated milk can vary considerably, often it is nearly normal, but frequently it is slightly diminished. Feser has given the following example of such adulteration:

The unadulterated milk had 3.95 per cent., fat; 8.9 per cent., solids not fat; 1.031 specific gravity; by partial skimming, it was changed to 2.19 per cent., fat; about 8.9 per cent., solids not fat; 1.034, specific gravity; by the addition of water it was further changed to 1.21 per cent., fat; about 8 per cent., fat free solids; 1.0305, specific gravity.

Decisive points for determining if such adulterations exist are the low solid contents, the low fat per cent., the almost normal specific gravity of the milk, the increased specific gravity of the solids (m) which, in the above example, was changed from 1.305 to 1.473, and in the low specific gravity of the whey. If nitrates are proven in the milk there is further support for the conclusion that it is watered.

When a sample of adulterated milk can fairly be compared with another which is known to be unadulterated (samples taken from the same dealer the same day, milk of a large herd, etc.) [or with an accepted standard] one can form an opinion of the extent of the adulteration by means of a formula derived from Böhmländer:

$$M \quad \frac{R}{r} \times w - W$$

$$E \quad 100 \left(1 - \frac{fR}{Fr}\right)$$

M shows the quantity of water added to 100 grm. of milk; W is the per cent. of water in the unadulterated and w in the adulterated, or suspected, sample; R and r are the percentages in these two samples of solids not

fat; E represents the percentages of fat removed by skimming, while F and f show the percentage of fat in the two samples.

In the above case one could find by computation:

$$M = \frac{8.9}{8} \times 90.79 \div 87.15 = 1.112 \times 90.79 - 87.15 = 13.81$$

$$E = 100\left(1 - \frac{1.21 \times 8.9}{3.95 \times 8}\right) = 100\left(1 - \frac{10.77}{31.60}\right) = 66$$

Or, in other words, about 14 grm. of water are added to each 100 grm. of milk and about 66 grm. of fat have been taken from each 100 grm. of fat.

The effects of the various adulterations may be shown in tabular form as follows:*

	Specific gravity of the milk.	Specific gravity of the whey.	Percentage of fat.	Percentage of solids not fat.	Specific gravity of the milk solids.	Percentage of fat in the total solids.	Percentage of ash.	Presence or absence of nitrate.
Normal milk	1.029 to 1.034 aver. 1.032	1.029 to 1.031	3 to 5	8.5 to 10.5	1.30 to 1.34	20 to 34	0.7 to 0.75	0
Skimmed or diluted with skimmed milk	higher	no change	lower	very slightly higher	higher	lower	higher	0
Water added	lower	lower	lower	lower	no change	no change	lower	+ or 0
Skimmed and water added	little change	lower	lower	lower	higher	lower	lower	+ or 0

Although each form of adulteration has its own characteristics yet, in practice, it is often very hard to determine whether a slight adulteration has occurred, because the composition of milk, as explained above, differs so much physiologically—and with the same animal from day to day. Unless there is a distinct departure from the normal, one should be careful in expressing his opinion, especially if he does not know the herd con-

*This table is changed somewhat from the one prepared by Jensen [L. P.]

cerned. Usually, the presence of nitrates is positive, still it must not be forgotten that when the milk can is rinsed a little water may be left, which, if it is rich in nitrates, may cause the milk to show a slight reaction, so that it might appear that water has been intentionally added. Usually water does not contain such a quantity of nitrates as to cause a suspicious reaction when the milk has not really been adulterated.

d. **Adulteration of partly skimmed and skimmed milk.** In most cities no minimum limit is fixed for the fat content of the half skimmed and the skimmed milk, and the only form of adulteration to be considered in this connection is the addition of water. This causes a lowering of the specific gravity of the milk (from 1.030 to 1.036 to from 1.032 to 1.040) and whey, as well as a diminution in the amount of solids. A possible trace of nitrates proves that the milk has been watered. In cities, in which the minimum limit of fat content for partially skimmed milk or skimmed milk has been established, the milk is, of course, considered adulterated when it falls below this standard. [In some places there is a standard of 9.25 per cent. total solids for skimmed milk as provided by the U. S. Department of Agriculture.]

e. **Adulteration of cream.** Cream is sold in different forms, with fat content varying between about 10 per cent. and 30 per cent. (40 per cent.). In some cities, the minimum content of different grades is defined, so in such cases public control must be extended to determining the amount of fat in cream. Of the different adulterations, the addition of starch and flour are to be mentioned particularly. This is done to make the cream thicker and to give it the appearance of being better than it really is. In raw cream, the proof by microscopic examination is simple, as the starch grains are

shown as irregular, round concentrically formed bodies. Amyloid bodies have been found in milk by Herz; these are like similar bodies previously found in the prostates, and somewhat resemble starch grains, but are hardly to be found in such great quantity that, in practice, they have any influence on this examination. After the cream is boiled, the starch grains burst, and cannot be recognized under the microscope. In this case, the chemical test must be applied, which may be used with raw cream also. The simple addition of a diluted solution of iodine, in many cases, gives the milk the well-known blue color; it is better, however, to add a little acetic acid, boil and filter and apply the iodine test to the filtrate. [The presence of "viscogen" is indicated by the greater percentage of ash.]

The detection of other foreign substances, as white earth, emulsion of brain substance, etc., is best made by means of microscopic examination.

VI. PUBLIC SUPERVISION TO PREVENT THE SALE OF DETERIORATED MILK

The public should not only make and enforce regulations regarding the production and handling of milk to prevent adulteration, but it should make regulations to prevent milk being sold in a damaged or spoiled condition and, by frequent inspection, these regulations should be enforced. The milk samples that are taken must not only be used for the purpose of determining possible falsification but, at the same time, they should be subjected to a number of other examinations.

a. **Determination of the appearance, odor and taste.** All milk differing from normal in color or appearance (mixture of blood or exudate, abnormal secretion, secretion of coloring matter, bacterial alterations), or by odor or taste (abnormal composition, the excretion of odorifer-

ous substances, absorption of strongly odorous matter, addition of foreign matter, bitter, stale, sour, microbic changes) must not be sold and should be condemned.

b. **Determination of the reaction.** This may be done by using red and blue litmus paper. Normal, quite fresh milk has an amphoteric reaction. If the test shows excessive alkaline or acid reaction, it should be examined more closely. An alkaline reaction is frequently shown in the milk of old milking cows; mixed milk, on the contrary, is never alkaline. Sometimes an alkali is added; if so, it can be proven by the test previously mentioned, or, quite easily, by titrating with tenth-normal sodium hydrate solution, with which phenolphthalin is used as indicator. Normal milk shows an acid reaction to phenolphthalin, so that from 18 to 19 c.c. of tenth-normal sodium hydrate solution must be added to 100 c.c. of milk to make the red color appear; if the milk becomes red at once when phenolphthalin is added, then it is abnormally alkaline and, as a rule, alkali has been added; if a smaller quantity of sodium hydrate solution is necessary, the milk may either have been treated with alkali or diluted with water.

If the litmus paper indicates an acid reaction, the degree of acidity of the milk may be determined by means of titrating with tenth-normal solution of sodium hydrate, using phenolphthalin as indicator. If, to neutralize 100 c.c., requires more than 18 to 19 c.c. of tenth-normal sodium hydrate solution, then the formation of lactic acid has commenced, and its extent can be measured exactly by determining the amount of standard alkali required to neutralize it.

For titrating, an ordinary burette is used with a scale divided into spaces showing 0.1 c.c. After the addition of about 0.25 c.c. phenolphthalin solution to the milk, the standard sodium solution is dropped in, little by little,

until, after thorough shaking, the milk becomes faintly reddish. Then the exact amount of solution that has been used for neutralization is read off, and the degree of acidity determined. If one has to make many titrations it is most convenient to use a burette with a supply from a larger tank; such a titrating apparatus can be procured from any dealer in chemical apparatus.

[A rapid method for determining the acidity of milk has been devised, which depends on the use of an accurately measured amount of alkali dispensed in the form of a tablet. This makes it possible to quickly prepare a standard solution, and the method is very useful for inspections in the field. If the indicator, phenolphthalin, is included in the tablet, the test is still more convenient. It is made as follows:

Tablets are dissolved in a measured quantity of distilled water, sufficient to give a solution of standard strength (usually five tablets make 100 c.c. of solution, but this varies with the brand of tablet and the manufacturer's instructions must be observed) 18 grm. (17.6 c.c., being measured in the pipette used for the Babcock test) of milk are measured into a white porcelain cup and the alkali solution is added from a measure (burette or graduated cylinder) until the pink color becomes permanent. The amount of solution used shows the percentage of acid in the sample.

If a standard of 0.2 per cent. lactic acid has been adopted, then the amount of alkali solution required to show any excess above this limit may be placed directly in the cup and the measured sample of milk added to it. If the pink color remains, there is less than 0.2 per cent. of acid in the sample; if it disappears, there is more than 0.2 per cent. of acid. L. P.]

Only a few German regulations give a standard for the acid permitted in market milk. Sometimes, the

requirement is made that the milk shall withstand the test of boiling it in a test tube without the separation of flakes or curds, and be able to withstand the, so-called, alcohol test, which is made as follows:[56]

Exactly equal parts of milk and alcohol (68 per cent.) are carefully mixed in a tube and observed closely. Fresh milk shows no precipitation; in that which is beginning to sour, fine flocules are deposited on the walls of the glass and, with greater acidity, flakes and lumps are separated.

c. **The fermentation test** is used to show whether there is an excess of bacteria of putrefaction in the milk. It consists simply in incubating a sample of milk at body temperature for 8 to 16 hours, followed by an examination as to its appearance, odor and flavor. The examination is easily made as follows: Into large test tubes holding at least 25 c.c., that have been carefully cleaned and sterilized, the milk samples, warmed to about 36° C. (97 F.), are poured. The tubes are closed by cotton and placed in an incubator or closet, where they are kept at 30° to 35 C. (86° to 95 F.). In the course of eight or ten hours, and again later, the contents of the tubes are examined. Good, undeteriorated milk is then sour and curdled and forms a homogeneous coagulum, without much separation of whey or formation of gas. Frequently, gas bubbles have split the coagulum and considerable fluid has separated. This change, however, does not necessarily signify that the milk was particularly rich in bacteria of putrefaction. On the other hand, if the milk curdles and has an offensive odor, or

[56] As a result of boiling, separation occurs not only where the milk has reached a certain degree of acidity but also in cases where, as a result of disease of the cow, abnormally large quantities of albumin and of globulin are present, or when there is admixture of colostrum.

if the coagulum is beginning to dissolve, or if the milk remains in a fluid state but has a bad odor and taste, these are signs that the milk is contaminated with bacteria of putrefaction. In the application of this test, it is important not to allow the milk sample to stand too long before the examination is begun, and precautions must be taken to prevent contamination while gathering the sample and during the test.

In pasteurized milk, the fermentation test may give general information concerning the bacterial content, through noting the time that passes until appreciable changes take place. Usually such milk does not "sour." But no precipitate conclusion should be drawn from the results of this test.

By boiling the milk for a short time and then incubating the samples, a serviceable guide can be obtained concerning the quantity of the spore bearing bacteria in the milk. These will survive the heating, and, as they are not checked in their growth by the lactic acid forming bacteria, they increase rapidly and cause the milk to curdle, by the action of ferments.

[Russell [57] describes a curd fermentation test used by cheese makers, as follows: "When the milk is 95° F., about 10 drops of rennet extract are added to each sample and mixed thoroughly with the milk. The jar should then remain undisturbed until the milk is completely curdled; then the curd is cut into small pieces with a case knife and stirred, to expel the whey. The whey should be poured off at frequent intervals until the curd mats. If the sample be kept at blood heat (98° F.), for six to eight hours, it will be ready to examine.

"The curd from a good milk has a firm, solid tex-

[57] H. L. Russell, Dairy Bacteriology, Sixth Edition. Madison. 1905.

ture, and should contain at most only a few small ' pin ' holes. It may have some large, irregular ' mechanical ' holes where the curd particles have failed to cement. If gas-producing bacteria are very prevalent in the milk, the conditions under which the test is made cause such a rapid growth of the same that the evidence of the abnormal fermentation may be readily seen in the spongy texture of the curd. If the undesirable organisms are not very abundant and the conditions are not especially suited to their growth, the ' pin ' holes will be less frequent.

" Sometimes the curds show no evidence of gas, but their abnormal condition may be recognized by the ' mushy ' texture and the presence of ' off ' flavors, that are rendered more apparent by keeping them in closed bottles. This condition is abnormal and is apt to produce quite as serious results as if gas was formed."

Curd fermentation tests have been suggested for use in connection with the supervision of market milk, and C. E. Marshall has made some observations that tend to show their usefulness for this purpose. L. P.]

To make regulations in relation to the behavior of milk to these tests would be premature. The general requirement that market milk, and especially infants' milk, shall not be rich in bacteria of putrefaction is sufficient for the present.

d. **Bacteriological examinations** are made when more information is desired regarding the number and kind of bacteria in milk. As has been said, this differs greatly, even in freshly drawn milk, and it is scarcely possible to state a passing average for the bacterial content of market milk. Nor does it seem to be possible to establish a maximum by ordinance, the violation of which would lead to the condemnation of the milk. Yet, it is of importance to health officers to have an examination made of the number of bacteria in milk sold, since, by

so doing, an opinion can be formed as to the genuineness of the claims of the milk companies, as well as the cleanliness and care with which the milk has been handled from the time it was drawn until it was sold. There are special reasons for making regular bacteriological examinations of nursery milk; it must be required not only that this shall come from healthy animals and not be exposed to infection with pathogenic bacteria, but, at the same time, it is well to require that it shall not contain an excess of bacteria at the time it is delivered to customers. In this connection, it would be very advantageous to make a stipulation to the effect that vessels [bottles] in which infants' milk is sold shall be provided with a label giving the day on which the milk was produced. A bacteriological examination of infants' milk is of importance as indicating the thoroughness and effectiveness of the methods of the concern and as indicating the need, perhaps, of subjecting these methods to thorough revision.

There are other reasons for establishing a bacteriological examination of pasteurized (and sterilized) milk, since, in this way, most important information may be gained concerning the reliability or the inefficiency of the methods in use by the various concerns. It would also be of advantage, in connection with this inspection, to require that the containers of pasteurized milk shall be marked with a tag showing the day and method of pasteurization (or sterilization).

The counting of bacteria in milk is not a difficult matter, but when many samples are to be examined in this way much time is required. The method is, in general, the same as that used for estimating the number of bacteria in water or other fluids (see the text-books on bacteriology). It is best to use gelatin that has been made with milk. A good way is to add 100 grms. of gela-

tin to one liter of milk, boil, filter, neutralize, boil and filter again. Or, one can use agar-agar in place of gelatin in making this culture medium. In this case, it is necessary to first remove the casein by the use of rennet. By this method, one may obtain agar or gelatin that is fairly transparent. The culture media should be placed in test tubes in the usual way. The examination can be made as follows: By the use of an ordinary cover glass preparation, examined under the microscope, one ascertains whether the milk is especially rich in bacteria. If there are only a few bacteria, usually three gelatin tubes will suffice, otherwise four or five must be used. One c.c. of milk is measured out and is mixed with 9 c.c. of fluid gelatin in a test tube. After mixing, one c.c. of the mixture is placed in another tube containing 9 c.c. of fluid gelatin. From this mixture a third tube is inoculated, and so on. In this way different dilutions of milk are obtained. Tube no. 1 contains 0.9 c.c of milk; no. 2, 0.09; no. 3, 0.009; no. 4, 0.0009; no. 5, 0.0001. If nothing is taken out of tubes 2, 3 and 4 for the purpose of making further dilutions, they contain 0.1, 0.01 and 0.001 c.c. of milk. Of course one can make mixtures in any other desired proportion.

After making the proper dilutions the fluid is poured in a Petri dish which, of course, must have been sterilized. After the mass of gelatin becomes firm, the covered dish is put away and is kept at an appropriate temperature. In the course of time more or less colonies form on the gelatin, these are counted on the whole plate or on a definite sub-division, and by this means the approximate number of bacteria in one c.c. of milk may be estimated. The result of the count is by no means exact for a number of reasons, but this method gives an approximation that is sufficient for practical purposes. [The milk may be diluted with water instead of being

diluted through the gelatin tubes. Agar-agar is preferred to gelatin because it can be used for plates to be incubated. If comparative counts are to be made the apparatus and temperatures of incubation and the character of culture media should be the same. Porous Petri dish covers are preferred to glass covers because they tend to prevent spreading colonies. For a description of the method used in the bacteriological examination of milk in the laboratory of the Boston Board of Health see a paper by Slack in the Journal of Infectious Diseases, Supplement No. 2, February, 1906. L. P.]

The detection of specific pathogenic bacteria is so difficult and the examination gives such unreliable results that practically it is not worth while to search for them. The bacteria of typhoid fever and diphtheria have rarely been discovered through the use of cultural methods; the tubercle bacillus may sometimes be discovered under the microscope but usually it is present in such small amounts that it cannot be detected. The best way to examine milk for tubercle bacilli is by inoculation of experimental animals. A conclusion, however, cannot be drawn from this experiment until one or two months have elapsed.

e. [**Examination for pus.** The examination of milk for pus was first suggested by Dr. Stokes, of Baltimore, and has since been carried out in a number of public health laboratories in different parts of the United States. The researches of Stokes, Bergey, Stewart, Doane, Slack, and others have shown that cells are present in practically all samples of milk and that in some samples the cellular content is much higher than is usual. Where the number of cells is high it is customary to regard them as pus cells, but there is no general agreement as to where the line should be drawn. The question is a difficult one because pus cells and dead leucocytes

are morphologically the same and so can not be differentiated by their appearance alone. Doane has proposed that milk shall be regarded as containing pus if there is high cellular content accompanied by threads of fibrin. Bergey proposes that pus shall be diagnosed if there are 10 cells to the field of the 1/12 immersion lens. Stewart centrifuges 1 c.c. of milk in small tubes and if he find 23 cells to the field of the 1/12 immersion lens, when the sediment of this amount of milk is spread over 1 square cm., he reports pus. Slack proposes that the sediment of 2 c.c milk shall be spread over 4 square cm. and that pus shall be reported if 50 cells are seen to the 1/12 immersion field.

Since there is much doubt, in many cases, as to whether high cellular content actually denotes pus,—that is, as to whether the cells found are pus cells or leucocytes, and as to whether *the cells themselves* are injurious, it would appear to be desirable, for the present, to report pus only where there is high cellular content, as judged by one of the above methods, accompanied by the presence of streptococci. L. P.]

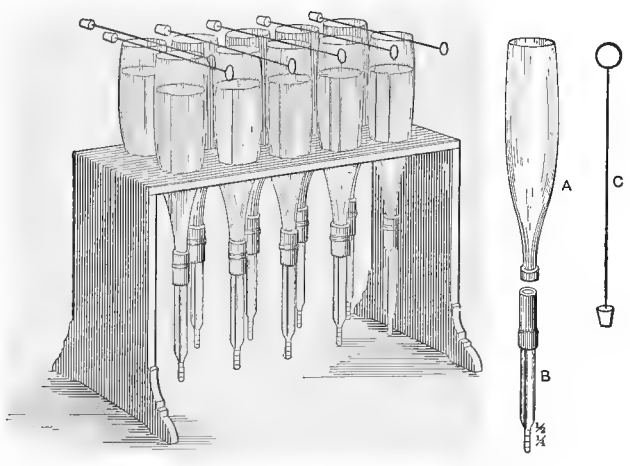
f. **Examination for dirt.** The sale of unclean or dirty milk should be forbidden. A number of cities in Germany have established the requirement that milk shall not contain over a definite amount of dirt; the limit varies from 5 to 10 milligrams of dry dirt to a liter of milk. An examination for dirt can be made as follows: The milk is placed in bottles, which are centrifuged, the milk is decanted and the sediment is dried at a temperature a little above that of boiling water. This material is weighed and its quantity per liter is calculated.

Instead of this rather formidable method it is usually sufficient to centrifuge the milk and then measure the sediment. Or, one can pour the milk in a high glass of conical shape and ascertain the amount of sediment

that collects in a given time. Gerber has constructed a special apparatus for this purpose by means of which a fair approximation of the amount of dirt in milk can be made by simply measuring it.

Generally, the only requirement on this point is that market milk shall not deposit visible sediment upon standing for two hours. [An apparatus for this purpose has also been devised by Otto, which can easily be understood by the accompanying figure. The bottle, A, which contains the milk is open at each end. The mouth of the bottle must be closed by a cork held upon a rod, C. A

FIG. 24.



Otto's apparatus for estimating dirt in milk.

fine tube, B, with a still finer point and closed at the thin end, is attached to the mouth of the bottle by a short rubber tube after which the cork on the rod C is withdrawn. The milk is then permitted to stand in this container, held in a rack, for a given time. At the end of this time, the stopper is replaced in the mouth of the bottle, the small tube is detached and the amount

of dirt is read from the scale. Stewart has devised a method that gives good results in the laboratory of the Board of Health in Philadelphia. It consists in the use of small glass tubes, open at each end; the lower opening is closed with a small rubber stopper. The tubes are filled with milk, and are centrifuged. The dirt is thrown upon the rubber stopper and adheres thereto when the stopper is withdrawn. It may easily be transferred to a slide for microscopic examination. Pus cells are collected in the same way. L. P.]

g. **Examination for preservatives.** One of the most important regulations with regard to the milk trade is that milk shall not be preserved by the use of antiseptics or alkalies, and one of the most important functions of the milk inspector is to see that this regulation is observed. An occasional test for preservatives may be made by standing the samples aside at room temperature. If the milk does not change within the time that is customary for good milk, the presence of artificial preservatives may be suspected. Methods for the detection of preservatives by chemical means have already been given.

If the increased keeping power of the milk is due to the addition of alkalies, this may be indicated by a simple test with litmus paper.

APPENDIX I.

THE REGULATIONS GOVERNING THE TRIFOLIUM MILK SUPPLY COMPANY IN COPENHAGEN, DENMARK.

I. THE WORK OF THE COMPANY SHALL BE UNDER THE SUPERVISION OF A COMMITTEE OF CONTROL CONSISTING OF A PHYSICIAN AND A VETERINARIAN.

II. THE OBLIGATIONS OF THE COMPANY TO THE COMMITTEE OF CONTROL SHALL BE AS FOLLOWS.

1. Milk may be taken only from herds that have been approved by the committee, and that furnish milk containing at least 3 per cent. fat.

2. Nursery (children's) milk shall come only from herds that are proven to be entirely free from tuberculosis by the use of the tuberculin test, and these herds shall be retested at least once a year. Milk may be received from a tuberculosis-free part of a herd only after the committee has investigated the conditions, and has given its approval. In this case, the healthy part of the herd is to be kept entirely apart from the reacting section, it is to be retested at least once a year, and the reacting animals are gradually to be disposed of.

If a calf plague (calf cholera, contagious pneumonia, pyæmia, etc.) occurs in the herd the committee may require shipments of milk to be discontinued until further notice.

3. The company pays one or more veterinarians, who are appointed by and are responsible to the committee of control.

Farms that supply the regular whole milk, skimmed milk and cream are to be inspected by the veterinarian twice a month, unless in summer the cows are kept stabled, in which case four visits per month are to be made. Herds that supply nursery milk are to be inspected the year through four times a month. Travelling expenses are paid by the company.

4. Nursery milk is to be shipped only in containers that

are easily distinguished by their shape and color from the containers used for the regular milk.

5. The company shall not employ any weakly persons, nor any that are afflicted with an infectious disease or with any repulsive skin disease, as tuberculosis or syphilis. Any employee so affected is to be dismissed.

If any one of the employees shall contract typhoid fever, gastric fever, diphtheria, scarlet fever, erysipelas or any other virulent infectious disease, the affected person shall not come upon the premises of the company or resume his work until he shall present a certificate from a physician to the effect that he is no longer capable of conveying infection. The same applies to employees in whose dwelling any one of the above named diseases may occur.

If any one of the employees shall be afflicted with discharging or suppurating wounds on the face, hands or arms or with any transmissible or repulsive disease or with severe diarrhœa, the affected person shall not be employed, during the continuance of the condition, in any work in which he would come into direct or indirect contact with milk, nor shall he be permitted to wash bottles.

Every employee who may not work on account of illness, or on account of disease in his family, *is to receive his full pay as though working.* A physician is appointed with whom the employees and the members of their families may consult and who shall make frequent visits to the dairy premises and keep an oversight of the employees as to their health.

The company shall keep a special record showing the employees that are ill, when they are laid off, and the nature of the illness.

6. The milk shall be cooled to 5° C. (41° F.) as it is received from the producers and shall be kept at this or a lower temperature.

7. All containers[58] are to be thoroughly cleaned by a method approved by the committee. The bottles for nursery

[58] The milk is delivered to customers only in sealed cans or, in the case of nursery milk, in bottles.

milk are to be cleaned and heated in accordance with the instructions of the committee.

8. The herds and all of the premises connected with the business are to be open to the members of the committee at all times. All necessary travelling expenses are to be paid.

9. All announcements and communications regarding the business, so far as these relate to the technical matters under the supervision of the committee, are to be approved by the committee before they are published.

10. A member of the committee of control shall be privileged to resign (*a*) at any time when in his opinion the hygienic regulations relating to the conduct of the business are not properly observed and, similarly, if later regulations made by order of the committee are not complied with, or (*b*) [under other circumstances] he may resign after three months' notice.

III. REGULATIONS CONCERNING THE PRODUCTION AND CARE OF MILK

A. THE HEALTH OF THE HERDS

1. The producer must agree to permit the veterinarian of the company to examine his herd as often as may be considered by the company to be necessary and he must give the veterinarian such information as he may desire in regard to the herd, the feeding and the milk.

The producer must agree to observe the instructions of the veterinarian.

2. The cattle that are designated by the veterinarian as tuberculous are to be removed from the herd at once, and, as soon as possible, they are to be sold or killed. Cattle that for any other cause are picked out by the veterinarian are, as he directs, to be removed from the stable or placed apart at one end; the milk may not be used and the cows may not be restored to their places with the herd until permission is given.

3. In case disease occurs between the visits of the veterinarian, and especially any of the following,—tuberculosis, inflammation of the udder, inflammation of the uterus, severe diarrhœa,—the affected animal or animals are to be isolated

and their milk must not be used. The company will continue to pay for this milk until the veterinarian makes an inspection. If a number of cows become diseased in such a way as to suggest the outbreak of an epizootic or poisoning the veterinarian and the business manager of the company are to be notified at once by telegraph or telephone.

4. The milk of newly purchased cows may not be used until these cows have been examined by the veterinarian and approved.

5. The producers of nursery milk are obligated to add no cows to their herds until they have been tested with tuberculin and are declared by the veterinarian for the company to be healthy.

All of the cows of the herd are to be tagged by the veterinarian.

The producer is required to have his herd tested with tuberculin at least once a year. The records of test are to be submitted by the veterinarian of the company to the committee.

If there is maintained on a farm a herd of reacting cows, the producer is required to dispose of these gradually and to take care that there is no contact between the healthy and the reacting cattle.

B. THE HEALTH OF THE PERSONNEL

1. The producer is required to observe the following rules in relation to the health of the persons who work in the stable or with the milk:

a. No one may be employed who is affected with tuberculosis or syphilis.

b. Persons who have discharging or suppurating sores or wounds on the face, hands or arms, or a disease of the skin of these regions, or that have severe diarrhœa are not under any circumstances to be permitted to come in contact with the milk.

c. Persons who live in a house where there is typhoid fever, gastric fever, diphtheria, scarlet fever or any other virulent infectious diseases are, likewise, positively prohibited from coming in contact with the milk until the local physician

certifies that they are no longer infectious. If, nevertheless, such persons should by accident come in contact with the milk, it is to be held back (not shipped) *and the company will pay the usual price for it,* unless the contamination was the result of connivance on the part of the producers.

d. The producer is required to use all possible care in keeping informed as to the condition of health of his employees so that every case of infectious disease may be discovered and isolated as soon as possible.

e. Once a year—soon after the "moving days"—a statement is to be submitted from the local physician to show the state of health of the persons on the farm and all cases of infectious diseases that he treated [on the farm] during the preceding half year.

2. If a case of typhoid fever, gastric fever, diphtheria, scarlet fever or any other virulent infectious disease occurs among the people living at the farmstead or among the people employed on the farm, the producer is obligated immediately to notify the manager of the company by telegraph or telephone. The milk shall be held back and shipments may not be resumed until the committee of control has given permission.

For all milk that is held back under these circumstances the company will pay full price.

C. FEEDING AND CARE OF THE COWS

1. All food must be quite fresh [*frisch*—not deteriorated]. Mouldy or otherwise damaged food must not be in the stable, or in the immediate vicinity. The veterinarian of the company has the right to inspect the food.

2. In summer, so far as possible, the cows are to be fed in the pasture. If it is necessary to feed them in the stable, the company is to be notified and then the producer is required to use care that the stable and the cows are kept as clean as possible.

The company reserves the right to forbid, if it is considered necessary, the stable feeding of cows that produce nursery milk.

3. The veterinarian shall be advised as to the composition of the feed. The following rules apply:

a. No roots may be fed to cows producing nursery milk except carrots and sugar beets, and of these not more than 20 kilos [40 lbs.] per day.

b. Cows producing regular milk may receive as much as 30 kilos [60 lbs.] per day, provided this amount does not cause diarrhœa.

c. Beet tops, beet trimmings, cabbage, distillers' slops, malt, etc., may not be fed.

d. For cows producing nursery milk, the following foods are prohibited: molasses, cotton-seed meal, green or dry buckwheat and mustard. These feeds may be given to other cows, but only in small quantities. Molasses must not be used if it produces any undesirable effect.

e. If rape seed is used, it must not contain any considerable quantity of oil of mustard, and before it is used it must be shown to the official veterinarian.

4. The producer is required, so far as possible, to forbid frequent and sudden changes of food.

5. Before the cows are stabled in the fall, the hair is to be clipped from the udder, tail and thighs.

6. The use of beast milk is forbidden until ten days after calving. The milk shall not be used from cows that have daily less than 3 kilos [3 quarts].

D. THE CARE OF THE MILK

1. Milking must be conducted with the highest degree of cleanliness and care. The following specific rules shall apply:

a. Each milker must always wear a milking suit and must be supplied with a towel. Clean water must be supplied in ample amount, so that the hands may be washed as often as necessary.

b. The stable must be so well lighted, and especially behind the cows, that those who do the work can see clearly enough to perform their work in an orderly and clean manner.

c. Immediately after milking, the milk is to be passed

through a fine metal strainer, which must be cleaned frequently.

d. The milk is to be cooled before it is shipped, at all seasons, and just after milking, by the use of a cooler, to at least 8° C. (46.4° F.).

e. Mucking out shall not take place until after the morning milking, and in the afternoon it must be completed at least one hour before milking.

f. Fresh cows [those giving beast milk], cows which give less than 3 kilos [3 quarts] a day, and cows that have been separated from the herd by the veterinarian shall have places in the end of the stable, so that it will not be possible for the milkers to mix their milk with that of the cows producing milk for the use of the company.

2. A sufficient supply of ice shall be available. For cooling, an apparatus is to be used that is set up in a light, clean room, that is used for no other purpose, and each time, before used, it is to be rinsed off with clean water.

3. The producer agrees to follow the instructions regarding cleanliness in the stable and the care of the milk that may be given him by the company or by their veterinarian.

E. DELIVERY

1. In the summer the transport wagons must be supplied with a cover to protect the milk cans from the sun.

Feed, fertilizer, etc., must not be carried on the same wagon with milk or with the cleaned milk containers.

2. The company furnishes the cans used for transporting the milk. Those used for nursery milk must not be used for other milk. Under no circumstances shall the cans be used for any purpose other than to send milk to the milk station. The cans are cleaned by the company before they are returned.

3. The producers are to rinse the cans in clean, cold water, and, if soiled during transportation, they are to be cleaned.

4. The producer is required to furnish a supply of good water for the cows and for cleaning the vessels and utensils that come in contact with the milk. Any suspected defect of

the water supply is to be reported at once to the committee on control.

F. OTHER PROVISIONS

1. The producer agrees to answer truthfully and honestly all questions from the company in regard to the milk supply.

2. It is agreed that the herds and premises where the milk is handled and cared for shall be open at all times to the members of the committee on control.

IV. INSTRUCTIONS TO THE VETERINARIANS

The veterinarians are appointed and can only be dismissed by the committee on control, and all instructions come from this committee.

A report is to be rendered to the committee on every visit to a herd, and this shall contain information in regard to: the total number of cows, the cows in milk, all cases of disease, whether cows have been sold or killed that were isolated as suspicious or diseased, the condition of the whole establishment in respect to cleanliness, the method of feeding and remarks on any pertinent subject.

[It is especially to be noted, in respect to the above regulations, that they are planned not for the purpose of measuring, by means of a laboratory examination, the extent to which milk has become contaminated, but for the purpose of *preventing contamination.*

The most injurious bacteria in milk are the pathogenic forms that come from diseased persons or cattle and the putrefactive organisms that come from diseased cows, dirty premises or utensils or faulty methods of milking or handling milk. The most important pathogenic forms cannot be detected in milk by the usual routine methods in use in milk laboratories, if at all. And if these organisms are detected by laboratory examination it is not until long after the milk has been consumed. Nor can the injurious saprophytes be identified in the laboratory until too late to prevent the use of milk con-

taining them. Hence, it must be clear that the truest protection to the consumer consists in guarding the source of the milk and the milk itself, from conditions that are known to be accompanied by danger of injurious contamination.

The value of laboratory examinations as to the number and kind of bacteria, pus cells and solid dirt is not under-estimated; it is very great as a measure of the thoroughness of the precautions taken on the dairy farm, and during shipping. But the value of this examination should not be exaggerated, as appears to be the tendency in some quarters, and it should not be thought that any laboratory examination can, with safety, be permitted to take the place of regular, expert veterinary inspections of the cattle, methods and premises.

The bacteriologic and microscopic examinations of milk that are made in public health laboratories keep contaminated milk from entering the market only in so far as they point out the necessity for the veterinary and sanitary control of dairy farms. (See quotation from Freeman on page 168.) L. P.]

APPENDIX II.

The following instructions in regard to the production of nursery milk are taken from a circular letter of May 27th, 1899, from the central government of Germany to the local governments.

NURSERY MILK

" The special establishments for producing and selling nursery milk, which have greatly increased in number in recent times, and which use special designations, as *sanitary dairy, health milk, children's milk, superior milk,* etc., are to be looked after with special care by the sanitary authorities. The general methods, the cleanliness of the stable, the storeroom, the utensils, the condition of health of the cows and their feeding and care are to be placed under veterinary oversight

" The stables shall be roomy, light and airy, and they shall have impervious floors and mangers of such description that they can be easily cleaned. Running water shall be provided for cleansing and the drainage shall be good. Only cows for the production of nursery milk shall be kept in such special stables and these cows shall be marked in some permanent way.

" It is not necessary to lay down special regulations for feeding such cows, but attention should be called to the known facts as to injurious effects of certain cattle foods on milk used for infant feeding.

" In general, the feeding of creamery refuse should be forbidden on account of the danger of spreading tuberculosis.

" The condition of health of cows designed for producing nursery milk is to be determined before they are placed in the empire. This examination is to be repeated at intervals of three months.

" A careful book record is to be kept of these examinations. The official who is charged with this oversight shall make an appropriate entry for each visit.

" The occurrence of any one of the following named diseases among the cows is to be reported at once to the official veterinarian: anthrax, contagious pleuro-pneumonia, foot-and-mouth disease, black quarter, rabies, cowpox, icterus, dysentery, inflammations of the udder, blood poisonings, especially pyæmia and septicæmia, putrid inflammation of the uterus or other febrile conditions, retention of the after-birth and conditions that result in the occurrence of discolored milk.

" Cows which show evidence of disturbance of digestion, of diarrhœa or pica, or cows that are suspected of being afflicted with tuberculosis shall at once be removed from the stable, until the animal is examined and the condition determined by the official veterinarian.

" It is not permitted to use as bedding soiled or refuse straw or other waste material.

" Cows for producing nursery milk shall be kept particularly clean. Before milking, the udder is to be carefully cleaned. The milkers must keep themselves thoroughly clean. They must wash their hands and arms with soap before milking, and wear a clean frock. Any person suffering with a contagious or eruptive disease must not be permitted to milk."

APPENDIX III.

Certified milk in Philadelphia is produced under the control of a commission organized in 1899 under the following plan:

1. There shall be a Milk Commission of the Philadelphia Pediatric Society, whose duty it shall be to have examined milk submitted to them by dairymen and certify as to the result of such examination.

2. The actions of the Commission shall be reported from time to time to the Society and shall be subject to its approval.

3. The Commission shall consist of four members besides the President of the Society, who shall be a member *ex officio*. The members shall be appointed yearly by the President as soon as possible after his election. The Commission shall elect a chairman and a secretary from their number.

4. No statement for publication or information to any dairyman shall be given by or in the name of any individual member, but only after consideration by the Commission and in the name of "The Milk Commission of the Philadelphia Pediatric Society."

5. The Commission will hold itself in readiness to examine milk from dairies desiring this examination, and to certify to the good quality of milk which comes up to the standards fixed by it. It is understood that only the milk of dairies, and not that of milkmen who merely serve milk bought by them, will be examined by the Commission.

6. The method of examination and certification to which the dairyman or his agent shall agree to submit shall be as follows:

7. The Commission shall select a bacteriologist, a chemist, and a veterinary inspector. The bacteriologist shall procure a specimen of milk from the dairy, or, preferably, from delivery wagons, at intervals to be arranged between the Commission and the dairy, but in no case at a longer interval than

one month. The exact time of the procuring shall be without previous notice to the dairy. He shall test this milk for the number and nature of bacteria present in it, to the extent which the needs of safe milk demand. He shall also make a microscopic examination of the milk for pus cells. Milk free from pus and injurious germs and having not more than 10,000 germs of any kind or kinds to the cubic centimeter, shall be considered to be up to the required standard of purity.

8. The chemist shall in a similar manner procure and examine the milk for the percentages of proteids, fat, sugar, mineral matter, and water present. He shall also test its chemical reaction and specific gravity, and shall examine it for the presence of foreign coloring or other matters or chemicals added as preservatives. Standard milk shall range from 1.029 to 1.034 specific gravity, be neutral or very faintly acid in reaction, contain not less than from 3.5 per cent. to 4.5 per cent. proteid; from 4 per cent. to 5 per cent. sugar, and not less than 3.5 per cent. to 4.5 per cent. fat in the case of 4 per cent. fat milk, and shall be free from all contaminating foreign matter and from all addition of chemical substances or coloring matters. Richness of cream in fat shall be specified and shall vary not more than 1 per cent. above or below the figure named in selling. Neither milk nor cream shall have been subjected to heat before the examination has been made, nor at any time, unless so announced to the consumer.

9. The veterinary inspector shall, at intervals equal to those of the bacteriologist and chemist, and without previous warning to the dairy, inspect the cleanliness of the dairy in general, the care and cleanliness observed in milking, the care of the various utensils employed, the nature and quality of the food used, and all other matters of a hygienic nature bearing upon the health of the cows and the cleanliness of the milk, including also as far as possible the inquiry into the health of the employees on their farms. He shall also see that the cows are free from tuberculosis or other disease.

10. The charges made by the experts shall be—for the veterinarian $10.00, and $5.00 for each of the others for each examination; this amount to be paid by the dairy at the time

of the examination and without regard to whether the report is favorable or unfavorable. The experts shall make their examinations when, and only when, notified to do so by the Commission. Any dairy the milk of which shall be found by the examiners to be up to the standard of the Commission shall receive a certificate from the Commission, which shall read as follows:

MILK COMMISSION OF THE PHILADELPHIA PEDIATRIC SOCIETY

Date... .....

The Veterinary Inspector of the Commission has examined the dairy of Mr. ..... and reports it to be well kept and clean, and the cows to be in a healthy condition.

The Bacteriologist reports that the milk does not contain germs beyond the limits of the standards of the Commission.

The Chemist reports that the milk is of standard richness, and that he has discovered in it no impurities, coloring matters, chemical preservatives, or harmful substances.

The Commission certifies to these statements of the examiners. It is understood and agreed to by the said Mr. ..... that this certificate is good for not more than ..... from date, when another examination is to be made.

[Signed by the Commission.]

11. In case an examination shows the milk not to be up to the standard the dairy may have a re-examination made within a week or within a short time, at the discretion of the Commission.

12. Milk furnished by the dealers to whom certificates have been issued shall be furnished to consumers in glass bottles hermetically sealed in a manner satisfactory to the Commission. In addition to the sealing, and as a guarantee to the consumer that the examination has been regularly conducted, there shall be pasted over the mouth of the jar, or handed to the consumer with every jar, according to the discretion of the Commission, a certificate slip which shall read as follows:

PHILADELPHIA PEDIATRIC SOCIETY.

MILK COMMISSION CERTIFICATE.

.....

Milk from the dairy of Mr.....has been recently examined by the experts of the Milk Commission and found to be up to the required standards. Another examination is to be made within a month, and, if satisfactory, new labels for the bottles will be issued, dated

....

NOTICE THE DATES.

The blanks used by the experts of the Commission in reporting to the secretary are as follows:

REPORT OF VETERINARIAN.

Philadelphia, ...190...

Secretary of the Commission,

DEAR SIR:—I have examined, as requested by the Commission, the dairy of..... at..... and find the following conditions:—

I. .....milking cows.
.....hospital cows.
.....cows sick since last report.
.....dry cows.
.....cows recently calved.
.....cows added since last report.

Did they pass veterinary inspection and the tuberculin test before admission to the milking herd?.....
.....cows now in quarantine.
Total number of cows in herd.....of which.....
have been tested with tuberculin in the past year.

II. Food employed.

.....

.....

III. Source and character of water in dairy and stables.

.....

IV. Condition of Stables:
Ventilation..... Heat.....
Cleanliness, etc.....
Floors..... Troughs.....
Condition of other buildings.....

V. Health of employees and their families, as far as ascertained, is.....

VI. The general precautions of cleanliness in milking and the care of the milk are .....

I therefore recommend that milk from this dairy be submitted to the Bacteriologist and Chemist of the Commission for their examinations.

Yours truly,..... *Veterinarian.*

REPORT OF BACTERIOLOGIST.

Philadelphia,.....190...

Secretary of the Commission,

DEAR SIR:

At the request of the Commission, received on..... milk
....., 190.., cream from the dairy of..... labeled..... was obtained by me on..... 190.., at ..... Street, at .....o'clock, ...M., and examined at .....o'clock, ...M., with the following results—

milk

Number of bacteria per c.c. of cream.....

I have been unable to detect any pathogenic organisms or evidence of purulent inflammation of the udder.

milk

I therefore recommend the cream as coming up to the bacteriologic standards adopted by the Commission.

I find the bottles to be sealed in the manner prescribed by the Commission.

Yours truly,

..... *Bacteriologist.*

REPORT OF CHEMIST.

Philadelphia,.....190...

Secretary of the Commission,

DEAR SIR:

At the request of the Commission, received on..... milk
..... 190.., cream from the dairy of..... labeled..... was obtained by me on..... 190.., and examined with the following results:

Fat, (Leffman-Beam method,)	.....
Total proteids, (Kjeldahl-Gunning method, factor 6.25),	.....
Preservatives, added color and heat,	none.
Acidity,	.....
Specific gravity,	.....

milk

I therefore recommend the cream as coming up to the chemical standards adopted by the Commission.

I find the bottles to be sealed in the manner prescribed by the Commission.

Yours truly,

..... *Chemist.*

APPENDIX IV.

The following plan for estimating the quality of dairy farm conditions, and for making it possible to compare farms, was originated and arranged by R. A. Pearson, Professor of Dairy Industry at Cornell University.

The score card idea has been extensively employed in judging animals, plants, seeds, etc., but this is the first adaptation of this principle to the judging of such a complex object as a dairy farm, including all of the factors that enter into the production of sanitary milk. A special feature of this scheme is the division into groups; a low score in any group renders the whole inferior, no matter how excellent the other groups may be.

The general idea is an excellent one; it enables the inspector to record in convenient form a summary of the result of his inspection and, by this means, a comparison can readily be made between the conditions of a farm at different times. Some practice is required to obtain the best results from the use of this method.

Department of Dairy Industry, College of Agriculture, Cornell University.

Score Card for Production of Sanitary Milk.

Date..... Dairy of.....

		Perfect	Score
I. **Health of the herd and its protection**	Health and comfort of the cows and their isolation when sick or at calving time	45	
	Location, lighting and ventilation of the stable	35	
	Food and water	20	
	Total	100	
II. **Cleanliness of the cows and their surroundings**	Cows	30	
	Stable	20	
	Barnyard and pasture	20	
	Stable air (freedom from dust and odors)	30	
	Total	100	
III. **Construction and care of the utensils**	Construction of utensils and their cleaning and sterilizing	40	
	Water supply for cleaning and location and protection of its source	25	
	Care of utensils after cleaning	20	
	Use of small-top milking pail	15	
	Total	100	
IV. **Health of employees and manner of milking**	Health of employees	45	
	Clean over-all milking suits and milking with clean, dry hands	30	
	Quiet milking, attention to cleanliness of the udder and discarding fore milk	25	
	Total	100	
V. **Handling the milk**	Prompt and efficient cooling	35	
	Handling milk in a sanitary room and holding it at a low temperature	35	
	Protection during transportation to market	30	
	Total	100	
	TOTAL OF ALL SCORES	500	

If the total of all scores is	And each division is	The sanitary conditions are
480 or above	90 or above	EXCELLENT
450 or above	80 or above	GOOD
400 or above	60 or above	MEDIUM
Below 400	Or any division is below 60	POOR

The sanitary conditions are..... Scored by.....

APPENDIX V.

On account of its *historic value*, the following agreement, which was the first provision for the production of "*certified milk*" in America, is reproduced. The plan of the agreement originated with Dr. Henry L. Coit, of Newark, N. J., and the " party of the first party," of the contract is the Medical Milk Commission of Essex County, New Jersey. The date of this agreement was May 9th, 1893. It is still in force.

1. The party of the second part doth hereby agree to conduct such parts of his dairy as may be hereafter named, collect and handle its products in conformity with the following code of requirements, for and in consideration of the promised endorsement of the parties of the first part, as hereinafter indicated. The milk thus produced shall be known as *certified milk;* shall be designed especially for clinical purposes, and when at any time the demand shall be greater than the supply, and it is required by a physician, either for infant feeding or the diet of the sick, it is hereby agreed that such shall be the preferred purchaser.

2. The party of the second part further agrees to pay for chemical and bacteriological examinations of the aforesaid certified milk, at such time as in the judgment of the party of the first part is desirable.

3. He also agrees to defray the cost of a bi-monthly inspection of his dairy stock, or oftener, if necessary, by a competent and approved veterinarian, all of which persons, namely: the chemist, the bacteriologist, the veterinary surgeon, shall be chosen by the parties of the first part, to whom they shall render their reports in writing.

4. It is expressly understood and agreed, that the party of the second part shall not pay more than the sum of five hundred dollars in any one year, for the services of chemist, bacteriologist and veterinary surgeon, and the party of the

first part shall limit the expense of such service to that amount. It is furthermore agreed that the party of the second part, on receipt of a certified copy of the reports of the experts, shall mail to the persons indicated by the parties of the first part, and not to others, a duplicate printed copy of the aforesaid reports, bearing the signatures of the experts and the names of the physicians. The same to be issued at such intervals as in the judgment of the parties of the first part is desirable; also that the necessary expenditures for printing and circulation be met in the same way as herein provided for expert examinations.

LOCATION OF LANDS

5. It is hereby understood and agreed, that the lands used by the owners, agents or assigns of the dairy, conducted by the party of the second part, and employed for pasturage, or any lands that may hereafter be acquired for such purpose, or such lands as may be used for the cultivation of hay or fodder, shall be subject to the approval of the parties of the first part.

BUILDINGS

6. It is also understood and agreed, that the buildings, such as stables, creamery, dairy house and spring house, shall be constructed after the most approved style of architecture, in so far as construction may affect the health of the dairy stock, or the character and conditions of the milk.

7. The buildings, used for the housing of the animals, shall be situated on elevated ground, and capable of being properly drained.

8. Said buildings to be sheltered from cold winds, lighted and ventilated according to approved hygienic methods. The buildings shall be constructed so as to favor the prompt and easy removal of waste products.

9. The apartments used for the storage of either feed or fodder shall be removed from possible contamination by stable waste or animal odors.

10. All buildings shall, in addition to healthy location, approved construction and proper ventilation, be kept free from animal or vegetable matter in a state or process of decomposi-

tion or decay, and always free from accumulations of dust or mould.

THE WATER SUPPLY

11. The dairy shall be supplied with an abundance of pure water.

12. No water from shallow wells or springs holding surface drainage, shall be used for watering stock, cooling milk or cleaning vessels.

13. Nor shall any well or spring be located within three hundred feet of the stable.

SURROUNDINGS

14 It is further understood and agreed that the immediate surroundings of the buildings shall be kept in a condition of cleanliness and order. There shall not be allowed to accumulate in the vicinity any loose dirt, rubbish or decayed vegetable or animal matter, or animal waste.

15. Nor shall there be within three hundred yards of any building, any constantly wet or marshy ground, or stagnant pools of water.

16. Nor shall there be kept within three hundred yards of any building used for dairy purposes any fowls, hogs, horses or other live stock.

THE COWS

17. It is hereby understood and agreed that the following unhealthy conditions shall be a sufficient reason to exclude any animal from the herd used for any purpose in the aforesaid dairy: Any animal that is judged by a competent observer to suffer from tuberculosis, even though the disease be localized in a part distant from the vital organs.

18. Any animal with fever. Any animal suffering from septic absorption or other disease, following or associated with parturition.

19. Any animal suffering from mammitis or mammary abscess.

20. Any animal with persistent diarrhœa or any other abnormal physical condition, which could in any way be detrimental to the character of the milk.

21. It is furthermore agreed that when an animal shall be found by a competent observer to be in a state of ill health, prejudicial either to the other animals in the herd or to human health, the same shall be removed immediately, and if necessary, shall be killed.

22. It is also understood and agreed that the party of the second part shall exclude from the herd used for producing certified milk, immediately after discovery, any animal subject to the following conditions: Any animal that was bred through consanguinity within a period of three generations.

23. And from this time forth, any animal of those bred by the party of the second part, used for producing certified milk, that was not, as a heifer, kept sterile during its first twenty-seven months.

24. Any phenomenal milker, except that glandular disease or tuberculosis has first been excluded for a competent observer.

25. It is furthermore agreed that if at any time it is desired by the parties of the first part, that a different breed of milch cows should be substituted for the one in use, in order that the standards of quality in the milk may be raised, the party of the second part will endeavor to carry the same into effect.

HOUSING AND CARE

26. It is furthermore agreed, that the dairy stock employed in the production of certified milk, shall be properly sheltered from the influences of weather and climate prejudicial to their health; also that the animals shall be kept clean, groomed every day, and treated kindly at all times.

27. The waste products of the stable shall be removed so frequently, and the stable floor so thoroughly cleaned, that the same shall be as free as possible from animal odors.

28. It is also agreed that no milch cow shall be used for dairy purposes while in a state of excitement, either as a result, or during the period of estrux, or which has been made nervous either by heating, whipping, kicking, prodding or running.

FEEDING

29. It is hereby understood and agreed that the methods of feeding the cows furnishing the certified milk, shall be subject to the approval of the parties of the first part. The feed and fodder shall consist only of nutritious and wholesome materials; such as grass, clover and timothy hay, whole grain, or the entire result of the grist. No materials shall be employed which are or may become injurious to the health of the animals. There shall not be fed at any time, or in any quantity, either alone or mixed with other feed or fodder, hulls, screenings, wet or dry brewers' grains, oil cake, sour ensilage, the refuse from distilleries, glucose or starch factories, any waste by-product in the treatment of grain, low marsh grass, or any of the questionable or exhausted feeds or fodders employed either to increase the milking capacity of the animal, or that will produce an impoverished milk, or that will impart to it unnatural odors or flavors. Nor shall the cows be allowed to eat green or worm-eaten fruit, poisonous weeds or to drink poisonous or stagnant water.

COLLECTING AND HANDLING

30. It is furthermore understood and agreed, that the cows from which is obtained certified milk shall be milked only in a clean building, and not an illy-ventilated stable containing foul odors and bad air.

31. No animal furnishing certified milk shall be milked until the udder shall first have been cleaned in a manner approved by the parties of the first part.

32. No person shall be allowed to draw the milk that has not within fifteen minutes of the milking first washed his or her hands, using soap and nail brush, and afterward thoroughly rinsing the hands in clean water.

33. The person or persons engaged in milking shall also be dressed in clean over-clothes.

34. No person shall be allowed to draw the milk who has been engaged with the care of horses in the same clothing or without first washing his hands.

35. No milk shall be represented as certified milk that is not

received from the udder into vessels, and from these into cooling cans, both of which are perfectly clean and dry, having been cleansed and heated, at a temperature adequate to effect complete sterilization, since the last milking; and have been kept inverted in a clean, dry and odorless atmosphere.

36. No milk shall be represented as certified milk that has not been passed through a sieve of wire or other cloth, either while milking or immediately thereafter, having not less than one hundred meshes to the linear inch.

37. No milk shall be represented as certified milk that does not consist of the entire contents of the udder at each milking, including the fore-milk, middlings and strippings.

38. No milk shall be represented as certified milk that has been drawn from the animal at abnormal hours, such as midnight or noon; nor from any animal for a period of nine weeks before calving, or that has not been separated for nine days after parturition.

39. No milk shall be represented as certified milk, which has been exposed to the emanation or infection of any form of communicable disease, either in the person or persons handling the milk, or by accidental contamination in cleaning milk containers, or by the association of any person engaged in handling the milk, with person or persons sick of contagious disease.

PREPARATION FOR SHIPMENT

40. It is hereby understood and agreed, that all milk represented as certified milk shall receive every known detail of care that will promote its keeping qualities, and favor its safe transportation.

41. That the milk on being drawn from the cow, shall be treated by ice, or clean, cold water in motion and proper aeration, in order, first, to remove its animal heat, and second, to reduce its temperature to a point not above fifty degrees, nor below forty degrees Fahrenheit; said temperature to be acquired within forty-five minutes after milking, and maintained within the above limits while held for shipment, during its transportation and until it is delivered to the purchaser.

42. That the cooling of the milk shall not be conducted in the same building in which it is drawn, nor in an atmosphere containing dust or tainted with animal odors.

43. That all the foregoing provisions concerning the cleansing and condition of vessels or utensils shall be complied with in the said cooling process.

44. It is furthermore agreed, that no milk shall be represented as certified milk, that has been changed or reduced in any way, by the addition of water or any solid or liquid substance, in or out of solution, or the subtraction or removal, in any manner, of any part thereof.

45. It is hereby understood and agreed, that all milk to be represented as certified milk, shall be packed in flint glass quart jars immediately after it is cooled.

46. Said jars to be of a pattern approved by the parties of the first part.

47. It is furthermore agreed that the bottles or jars, before being used, shall be cleaned by hand, separately, with the aid of hot water, alkaline soaps, rotating brush and steam, and that they shall be rinsed in two separate baths of clean, hot water and then thoroughly dried and kept inverted until used, without covers, in a clean, dry atmosphere free from odors.

48. It is agreed that the jars shall be filled by a method approved by the parties of the first part.

49. That they shall be sealed after all air has been excluded, by the most approved device for closing them.

50. The bottles after being filled, shall be labeled across the cap, bearing the words "Certified Milk," with the name of the dairyman, together with the date of milking.

51. It is furthermore agreed, that no milk shall be sold as certified milk, that is more than three hours old when bottled, nor more than twenty-four hours old when delivered.

TRANSPORTATION AND DELIVERY.

52. It is hereby understood and agreed, that the transportation and distribution of all milk represented as certified milk, shall be conducted by the party of the second part, either in person or by persons employed by him.

53. That in transit, the milk shall not be exposed to any of the foregoing prohibitory conditions.

54. That it shall not be subjected to agitation.

55. That it shall not be exposed to the heat of the sun.

56. That the delivery wagons shall be so constructed that the required temperature of the milk may be maintained during transit.

57. That before the wagons are filled for shipment, the body, the trays and compartments shall be flushed with boiling water.

58. It is furthermore agreed that the distributing agents shall, during the transfer of the milk from the dairy to the purchaser, be subject to the following restrictions, namely:

59. That they shall use no tobacco or intoxicating drinks.

60. That they shall not collect the empty containers, nor receive money or milk checks from houses in which an infectious or contagious disease is known to exist.

61. It is also hereby agreed that the collection of empty bottles, from places where infectious or contagious disease is known to exist, shall be made by other persons that those employed to deliver the milk.

62. That these collections be made with wagons not employed in the distribution of the milk.

63. That before these empty bottles shall be returned to the dairy, they shall be carried to a separate building and first be subjected to the process of cleaning bottles indicated in a former clause of this contract.

64. It is hereby understood and agreed, that if any further precautions or changes in method, calculated to improve the quality of milk, or guard the same from impurities or dangers, are desired, that the party of the second part will cheerfully be governed by such additional rules and regulations as may be laid down by the parties of the first part.

65. It is understood and agreed by the party of the second part, the same binding the owners, agents or assigns of the aforesaid dairy, that the product known as *certified milk* shall be under the following restrictions in its sale, namely: That until the amount required within the boundaries of Essex

county shall first be supplied, it shall not be sold beyond these limits, except that the parties of the first part shall give their consent.

66. It is furthermore agreed by the party of the second part, the same binding the owners, agents or assigns of the aforesaid dairy, that in the event of a failure to comply with any or all of the requirements of the foregoing contract, the party of the first part shall reserve the right to withdraw from the contract, and publish the fact in such manner as they deem best.

67. Finally, it is understood and agreed that nothing in this contract shall prevent the obrogation of any of the provisions of the same, by the parties of the first part, provided that it shall be done for the purpose of substituting other provisions, designed to promote the objects of their organization.

68. It is further understood and agreed by and between the parties hereto, that the party of the second part shall be at liberty to cancel this agreement by giving two months' notice in writing, of his desire to do so, in case of inability for any reason, to comply with the terms of the same.

APPENDIX VI.

The Second Interim Report of the Royal Commission on Human and Animal Tuberculosis was issued in January, 1907. It presents the conclusions of the commission after thorough and extensive investigations covering more than five years.

The report is signed by Sir Michael Foster, Prof. G. Sims Woodhead, Prof. Sidney Martin, Sir John McFadyean and Prof. Rubert Boyce.

The following is an extract:

CONCLUSION

"We may briefly sum up the bearings of the results at which we have already arrived as follows:

"*There can be no doubt but that in a certain number of cases the tuberculosis occurring in the human subject, especially in children, is the direct result of the introduction into the human body of the bacillus of bovine tuberculosis; and there also can be no doubt that in the majority at least of these cases the bacillus is introduced through cows' milk. Cows' milk containing bovine tubercle bacilli is clearly a cause of tuberculosis and of fatal tuberculosis in man.**

"Of the sixty cases of human tuberculosis investigated by us, fourteen of the viruses belonged to Group I, that is to say contained the bovine bacillus. If, instead of taking all these sixty cases, we confine ourselves to cases of tuberculosis in which the bacilli were apparently introduced into the body by way of the alimentary canal, the proportion of Group I becomes very much larger. Of the total sixty cases investigated by us, twenty-eight possessed clinical histories indicating that in them the bacillus was introduced through the alimentary canal. Of these, thirteen belong to Group I. Of the nine cases in which cervical glands were studied by us three, and of the nineteen

* Original not italicized.

cases in which the lesions of abdominal tuberculosis were studied by us, ten belong to Group I.

" These facts indicate that a very large proportion of tuberculosis contracted by ingestion is due to tubercle bacilli of bovine source.

" *A very considerable amount of disease and loss of life, especially among the young, must be attributed to the consumption of cows' milk containing tubercle bacilli.* The presence of tubercle bacilli in cows' milk can be detected, though with some difficulty, if the proper means be adopted, and such ought never to be used as food. There is far less difficulty in recognizing clinically that a cow is distinctly suffering from tuberculosis, in which case she may be yielding tuberculosis milk. The milk coming from such a cow ought not to form part of human food, and indeed ought not to be used as food at all.

" *Our results clearly point to the necessity of measures more stringent than those at present enforced being taken to prevent the sale or the consumption of such milk.*"

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